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14. ABSTRACT

The Center of Excellence (COE) in High Power Gas Phase Electric and Hybrid Lasers (later changed to Center of Excellence for High Energy Lasers) was established by the High Energy Laser Division of the Directed Energy Directorate in the Air Force Research Laboratory to provide advanced educational opportunities for U. S. citizens in the area of high energy laser research and development. Using the combined efforts of the High Energy Laser Division, the Air Force Office of Scientific Research, the Air Force Institute of Technology, the University of New Mexico (UNM), and New Mexico Tech (NMT), a program was developed to recruit, educate, and train students in various projects of high energy laser research leading to Masters and doctoral degrees. Resources in the form of this grant were provided to UNM and NMT to support the students' classroom and laboratory endeavors. Air Force laboratories at Kirtland Air Force Base were made available to the students. In all, seven students and one post-doctoral fellow participated in the program that were directly supported by this grant. Nearly 20 other students have been part of the COE. This report discusses the research conducted by the grant students while participating in the COE.

15. SUBJECT TERMS

Center of Excellence, High Energy Lasers, Diode Pumped Alkali Laser (DPAL), Thin Disk Laser, mode suppression, photonic crystal fiber amplifiers

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THE UNIVERSITY of NEW MEXICO | SCHOOL of ENGINEERING

Department of Electrical & Computer Engineering

Final Report

The Center of Excellence in High Power Gas Phase Electric and Hybrid Lasers

(Center of Excellence for High Energy Lasers)

1 August 2006 – 31 July 2010

AFOSR Grant: FA9550-06-1-0508

Principal Investigator: John A. Gaudet

in collaboration with:
Air Force Research Laboratory
New Mexico Tech
Air Force Institute of Technology

AIR FORCE INSTITUTE OF TECHNOLOGY

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Executive Summary

In 2006, the Air Force Research Laboratory's (AFRL) Laser Division of the Directed Energy Directorate (RDL) formed an educational partnership[1] with the Air Force Institute of Technology (AFIT), The University of New Mexico (UNM), and The New Mexico Institute of Mining and Technology [now known simply as New Mexico Tech (NMT)]. The purpose of this partnership was to provide a mechanism to create a "Center of Excellence" (COE) for high power lasers through which the next generation of qualified Air Force laser scientists/engineers would be trained in the relevant fields of laser physics, optics, electrical engineering, plasma physics, and physical chemistry. While not officially a partner, the Air Force Office of Scientific Research (AFOSR) became an important player in the partnership as an interested party and for resources to provide students to AFRL and AFIT. The concept of this COE included the educational part (represented by AFIT, UNM, and NMT), the financial support part (AFOSR and RDL), and the research facilities part (AFIT and RDL). The main focus of this final report will be the educational portion of the COE as reflected in the AFOSR grant to UNM discussed below.

In order for the Air Force to implement this education partnership strategy, it was decided to generate a grant from AFOSR to UNM to provide the resources and personnel for professors, post-docs and students from both UNM and NMT. The program manager at AFOSR for this grant was originally Major Ryan Umstattd and soon became Dr. Robert Barker. This final report presents the results of this grant executed with UNM in July 2006. The original Principal Investigator (PI) for the grant at UNM was Dr. John K. McIver. Dr. McIver left the university in June 2008 and Dr. John Gaudet replaced him.

The proposal submitted to AFOSR by Dr. McKiver at UNM focused on research involving gas phase hybrid lasers, specifically a concept known as DPALs (diode pumped alkali lasers). This topic was selected because RDL wanted to use excess equipment at Kirtland AFB (adjacent to UNM) which was ideally suited for this type of research. Also, DPALs work was a perfect subject for new innovations that would be easily publishable without concern for security issues, a necessary requirement for university theses. Thus, the initial students, post-docs and research concentrated on DPALs work. Eventually, the scope of research was expanded beyond DPALs to include other high energy laser topics of interest to the Air Force such as fiber lasers and solid state lasers. This decision was agreed to by the HEL COE Board of Directors during a conference call on 7 April 2008 (see Appendix D).

The COE achieved the following significant milestones within the scope of this grant:

[1]EDUCATION PARTNERSHIP AGREEMENT ENTERED INTO BY THE DEPARTMENT OF THE AIR FORCE AS REPRESENTED BY THE AIR FORCE RESEARCH LABORATORY DIRECTED ENERGY DIRECTORATE AND THE AIR FORCE INSTITUTE OF TECHNOLOGY AND THE UNIVERSITY OF NEW MEXICO AND THE NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY, dated 18 December 2006. See Appendix A.

• Seven students from UNM and NMT conducted experiments, performed research, and received first-class mentoring in Air Force facilities from RDL scientists, UNM and NMT post-docs and faculty;
• The infrastructure available to UNM students for high energy laser research was significantly improved;
• NMT graduated one M.S. student who conducted his research at AFRL/RDL;
• Two papers were published in refereed journals by student on DPALs research.

The students directly supported by this grant and a summary of their research follows:

JOSH SHAPIRO - *A Smart Instrument for Characterization and Control of a Diode Pumped Alkali Laser*

The first student to complete the program and graduate through this UNM/NMT grant was Josh Shapiro. He conducted Diode Pumped Alkali Lasers (DPALs) research at the RDL COE facilities and studied under the guidance of Professor Scott Teare at NMT receiving his M.S. in Electrical Engineering. DPALs require narrow band optical pumping for efficient operation. Laser diode pump sources for DPALs are often narrow-banded by providing optical feedback using a diffraction grating. This optical configuration results in highly tunable laser diodes suitable for pumping DPALs which are unfortunately susceptible to mode-hopping that degrades the DPAL performance. Mr. Shapiro constructed a smart instrument to accurately control the wavelength and compensate for these instabilities. He produced high-fidelity maps of the instabilities over a two-dimensional tuning parameter space of diode current and grating angle. Mr. Shapiro observed a hysteresis effect that depended on the direction of both grating and current adjustment. He was able to demonstrate stable closed loop feedback control of the laser wavelength by adjusting the grating with a piezoelectric crystal. At the same time he could avoid the unstable regions of laser operation by adjusting the diode current.

NATHAN ZAMEROSKI - *Radiation Trapping and Quenching of Rubidium Flourescnce*

Nate Zameroski is a PhD student at UNM in the Optical Sciences and Engineering program jointly run by the Physics and Astronomy Department and the Electrical & Computer Engineering Department. He has completed all of his required course work and examinations and is near completion of his dissertation research on DPALs. Mr. Zameroski has published one article[2] on his research and has prepared a second paper for submission. His research is an experimental study using time-resolved fluorescence techniques combined with theoretical simulations to determine the quenching cross-sections of rubidium–methane and rubidium–ethane. Radiation trapping was significant under many of the experimental conditions (temperatures 40–130 ºC and pressures 50–700 Torr) and therefore Mr. Zameroski carried out a detailed analysis of the interplay between radiation trapping and quenching kinetics. Modifications of the Holstein equation for radiation trapping were implemented to account for

[2] N. Zameroski, W. Rudolph, G. Hager and D. Hostutler, "A Study Of Collisional Quenching and Radiation-Trapping Kinetics for Rb(5p) in the Presence of Methane and Ethane Using Time-Resolved Fluorescence," *J. Phys. B: At. Mol. Opt. Phys.* **42** (2009) 245401.

the quasi-2 level behavior of the Rb atom for high buffer gas pressures. New experimental results for the quenching cross-sections of methane and ethane determined by Mr. Zameroski were nearly two orders of magnitude smaller than previously reported.

OMAR QASSIM - *Development of an Optically Pumped Cesium Dimer Laser*

Mr. Qassim is seeking a Masters degree in Electrical Engineering with a concentration in optoelectronics from UNM. His research topic is the investigation of cesium dimer as an alkali gain medium for potential future use in high powered lasers. Topics that will be addressed are: (1) the suitability of Cs2 as a gain material for alkali lasers, (2) determine a suitable enclosure that allows temperatures of 180 °C to be reached, and (3) find a solution to stopping the material from reaching the windows and corroding the anti-reflection coating.

NISHANT PATEL - *Temperature Insensitive Double Tunnel Injection DWELL Semiconductor Lasers at 976 nm*

Major research efforts are being undertaken within the DoD to scale the output power to the many kW level of optically-pumped fiber amplifiers at 1064 nm. The cooling requirement of pump laser diodes sources used in these systems embodies a significant power footprint. Additionally, these cooling requirements add a significant factor in space and weight needs especially when the application involves a platform such as an aircraft. Thus, providing un-cooled pump laser diodes solutions is of great interest to AFRL.

The research goal of this study is to develop a novel semiconductor laser which emits at 976 nm while maintaining high wall-plug efficiency over a broad temperature range. Laser emission at this wavelength is suitable for pumping Yb^{3+} doped fiber amplifiers. Mr. Patel research is to improve temperature performance by broadening the gain spectrum through chirped multiple quantum wells (MQW) or through quantum dot structures.

FURQAN CHIRAGH - *Photonic Crystal Fiber Amplifiers*

Furqan Chiragh is a PhD student in the UNM ECE Department with an Optoelectronics concentration. He is currently working on his research proposal and conducting an extensive literature search. He originally started his literature search on the topic of photonic bandgap fibers for 589 nm light generation. However, this topic became unsuitable for a PhD after further investigation and review by others. Due to the end of this grant and lack of a suitable topic, for now, Mr. Chiragh has decided to work as a contractor with AFRL/RDL while still pursuing his education. His work assignment involves photonic crystal fiber amplifiers and this general area will be the subject of his dissertation.

LINDSAY QUARRIE - *Atomic Alkali Resistant Optical Thin Film Coatings*

Lindsay Quarrie is a PhD student at NMT pursuing his degree in Materials Engineering, Lasers and Optics. A key element in the DPALs concept is the optical gain cell. However, degradation has been observed in these cells reducing laser throughput and optical pump efficiency. Mr. Quarrie's research is to provide a fundamental understanding of the processes by which the observed degradation is occurring in order to determine a means of minimizing the damage to the optical windows in the gain cell while maximizing pump efficiency. Applying a top level robust thin film with consideration for surface, coating, interface and substrate properties may improve laser throughput, optical pump efficiency and survival of the gain cells. The overall goal is to find an optimum combination of materials allowing the selection, application and testing of potentially atomic alkali resistant coatings on selected substrates (for example quartz) under the conditions of atomic alkali rubidium laser excitation in the gain medium of a DPAL. Special attention will be given to thin film coatings than can be applied to lightweight materials and can withstand harsh laser and atomic alkali conditions but maintain high optical performance. The necessary properties of the coatings will be established and modeled in Mcleod thin film design and analysis program to extract optical constants of film materials for use in designs. Matlab simulations will also be used as a tool in modeling and prediction of the performance of the overall system including coupling efficiency and operational reliability of the laser system.

The most suitable materials will be initially determined by experimental selection/screening process of materials first in terms of optical properties, followed by atomic alkali corrosion resistance then finally energy throughput via the optical material/film windows to determine pump efficiency. Careful selection of coating and deposition techniques will depend on the compatible properties of coating and selected substrate, the environment and required optical performance of the gain medium. These are some of the key factors that will determine the type and technique for coating application, for example, plasma activated chemical vapor deposition (CVD) is a commonly used process for this type of coating application. E-beam and Ion hardening techniques using ion exchange, thermal evaporation and deposition are also other possible options.

These coatings will be inspected to measure surface morphology and thickness, surface changes, roughness, refractive index and adsorption using selected spectroscopic and microanalysis techniques after exposure to atomic alkali vapor. The ideal situation is a material that can be used in a gain cell without any coating that is lightweight and atomic alkali resistant. The correct application of high performance atomic alkali resistant coatings with low optical adsorption may provide a higher optical quality gain medium, better thermal conductivity and heat dissipation, better optical pump efficiency and operational reliability in DPALs than previous achieved.

NATASA VRETENAR - *Thin Disk Laser: Thermal and Optical Characterization and Optimization*

Ms. Vretenar has chosen the topic of high power Yb:YAG thin disk lasers (TDL) for her research as a PhD student at the Center for High Technology Materials at UNM. She will examine the characteristics of these lasers both experimentally and theoretically. Her detailed modeling approach of TDLs will include finite element analysis (thermal and stress) and geometrical/physical optics (to examine beam quality). Experimental data gathered includes thermal measurements of TDLs and output couplers, small signal gain, wave front, spectrum, and fluorescence measurements. The final goal of this research is an efficient, small volume, light weight laser with high power and a high quality beam.

ADDITIONAL ACTIVITIES

In addition to the student research, many other related activities and milestones were reached during the course of this grant. In order to recruit students for the program, many campus visits to undergraduate classrooms were made by UNM faculty and the RDL COE Director. The benefits and goals of the student grants that were available were presented to hundreds of undergrads during the grant period emphasizing that we sought U. S. citizens to explore graduate laser research for their specialty. Brochures about the laser COE was available as a handout and at a COE website (see Appendix B). Along with the active recruiting of undergraduates, many senior engineering students spent part of their summers and often used semester time to perform a research project under the guidance of RDL scientists and post-docs. While these students received no financial support, the experimental equipment, lasers, and safety exams/training were provided to them at no cost. Thus, many young and talented individuals were introduced to the laser research field beyond those formally in the program. A summary of this aspect of the laser COE can be found in Appendix C.

Finally, management of the COE grant to UNM was integrated into the overall COE for high energy lasers as described above. As such, the organization of activities was usually coordinated through this grant. For example, over a dozen conference calls were held with the key players, UNM, AFIT, NMT, AFOSR, and AFRL/RDL. The notes from these conferences are reproduced in Appendix D. In addition to the conference calls, face-to-face meetings were held in conjunction with technical conferences such as HEL Joint Technology Office (JTO) reviews and the Laser Ablation Conference.

I. Introduction

This first section of the report will discuss the administration of this grant from the AFOSR and how it was managed. You will find notes of all of the major decisions that were made regarding grant management in the appendix (D) where minutes from all of the conference calls are presented from late 2007 (when Dr. Gaudet was brought onboard to assist the Principal Investigator, Dr. McIver) until the grant's end in July 2010. Next, a discussion of each student that has been funded through this grant from both UNM and NMT will be presented. In these chapters, the research goals of each student and their progress towards their advanced degrees are discussed. Since some of the students only officially came on board with the grant during the last year, their study program is only partially complete. In those cases where the student has not yet graduated, a follow-on grant from AFOSR has been awarded to UNM to ensure these "legacy" students from the original grant can continue their education uninterrupted. The appendices in this report provided additional detail on the AFRL HEL COE including a copy of the educational partnership agreement setup for the COE, non–grant student participation, undergraduate student activities in the COE, equipment augmentation done through this grant for the students, and minutes from various meetings and conference calls held during the UNM grant.

The High Energy Laser Center of Excellence (HEL COE) was established in 2006 at AFRL/DEL (now AFRL/RDL) to foster the education and training of the next generation of engineers/scientists in the multidisciplinary fields of laser research: electrical engineering, physics, chemistry, and mechanical engineering. While the COE is a broad concept integrating the goals of several Air Force organizations (RDL - the High Energy Laser Division, AFOSR - the Air Force Office of Scientific Research, AFIT - the Air Force Institute of Technology), this report concerns the grant award to The University of New Mexico (UNM) originally titled "AFOSR Center of Excellence in High Power Gas Phase Electric and Hybrid Lasers." This award, and its sub award to NMT (New Mexico Tech) provided the resources from AFOSR to recruit, educate and train students in the appropriate disciplines required to perform high energy laser research for the Air Force and for the Department of Defense, in general.

The original proposal contained suggested research topics for student candidates in the area of diode pumped alkali lasers, or DPALs. Hence, the first several research projects selected by students at both UNM and NMT were from this area. In part, DPALs was chosen because there existed all the necessary laboratory equipment and laboratory space at AFRL to conduct this research. Since one of the criteria for a project was to have the students work with AFRL scientists doing their theses at Kirtland AFB NM, DPALs provided an ideal subject. In addition, DPALs was considered a very new area of research that had many fundamental questions to be answered. Since the student research had to be "publishable" for academic credit, DPALs was also considered a very appropriate topic by AFRL. Over the course of this grant, the restrictions on the topic and where the research had to be accomplished was loosened by vote of the Board of Directors for the COE. This is all documented in the many conference calls conducted throughout the grant and the notes from these calls can be found in Appendix D.

II. New Mexico Tech Student - Josh Shapiro

Mr. Shapiro was the first HEL COE student to receive his degree. He studied under the supervision of Professor Scott Teare in the EE Department of NMT and conducted his research at AFRL's COE facilities on Kirtland AFB. His mentor at Kirtland was Dr. David (Tony) Hostutler. Scott graduated in December of 2008 with his M.S. in Electrical Engineering with a thesis entitled, "A Smart Instrument for Characterization and Control of a Diode Pumped Alkali Laser.[3]"

1. Introduction

The design of efficient DPALs poses considerable challenges. Current high power designs specify multiple high power narrow-band diode lasers all under active wavelength control and pumping a specific alkali vapor resonance. The narrow-banding process introduces complexities into the diode laser geometry which can cause instability in the laser wavelength and power. Wavelength instabilities, called mode-hopping, are widely recognized as problems, and methods to achieve larger mode-hop free tuning ranges are constantly being developed. However, if mode-hopping cannot be eliminated, then DPAL designers will need an effective and simple method for mitigating its effects. This thesis proposes that if the laser wavelength, stability and mode hopping can be mapped and measured, then mode-hops can be avoided and stable laser operation can be attained. This was demonstrated by developing a smart instrumentation system to collect high fidelity data to probe the wavelength and stability of a diode laser. The instrument was designed with the capacity to operate as a control system in order to test potential wavelength control algorithms. A modular architecture was chosen so that future DPAL subsystems can be cohesively integrated.

2. Design of Modular Instrument

Mr. Shapiro designed and implemented a custom smart instrument that performs high fidelity data analysis of the operating modes of an external cavity diode laser. It is a modular design wherein functional blocks perform specific tasks that are coordinated by a control computer which interfaces with the user.

The design requirements for this thesis consisted of the following primary and derived tasks:

- Primary tasks
  - Map absorption and mode-hopping over dense grid of laser tuning parameters
  - Perform closed loop feedback control of laser wavelength

- Derived tasks
  - Measure attenuation of laser light in alkali vapor

[3] Shapiro, J. N. (2008) "*A Smart Instrument for Characterization and Control of a Diode Pumped Alkali Laser,"* unpublished thesis, New Mexico Institute of Mining and Technology.

- Measure noise power in detected signal
- Modulate laser wavelength with signal of known frequency and phase
- Cross-correlate detected signal and modulation signal
- Control data collection and laser tuning with computer

The implementation of the instrument for mapping the ECDL operating regions has been partitioned into three functional blocks as depicted in Figure 1. The control computer is responsible for interfacing with the user, managing data, and executing scripts which coordinate the laser control and data acquisition. It currently performs some of the processing tasks such as noise power computation and cross-correlation, but these tasks could be moved into another module. Another module controls the laser tuning parameters and responds to queries on laser status, and a data acquisition module generates the modulation waveform and digitizes data from the experiment sensors.

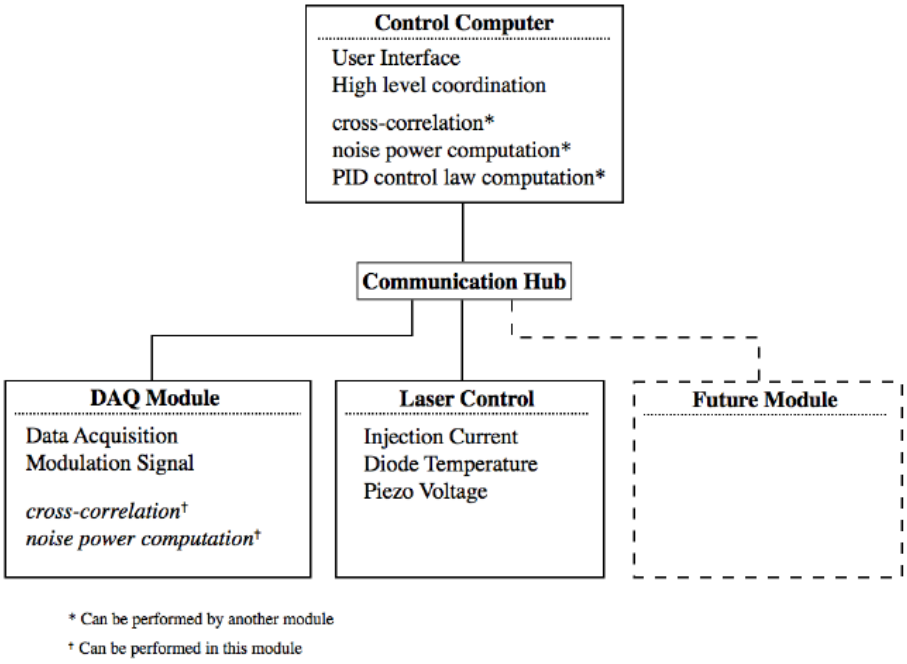


Figure 1. *A functional diagram of the instrument design. Processing requirements are divided among multiple modules making the instrument scalable.*

Absorption of light in an alkali vapor is measured by splitting the laser beam into two beams of equal intensity. One beam, the reference, is directly incident on a photo-detector; the other beam, the probe, first passes through a heated (between 60 and 100 degrees centigrade) rubidium vapor. Measurement of the absorption coefficient requires proper calibration and consideration of scattered light, however attenuation can be measured simply as the probe beam intensity divided by the reference beam intensity. The data acquisition module must sample the output of two photo-detectors simultaneously so that attenuation can be computed. A block diagram of

the instrumentation and experimental setup and a picture of the setup are shown in Figures 2 and 3.

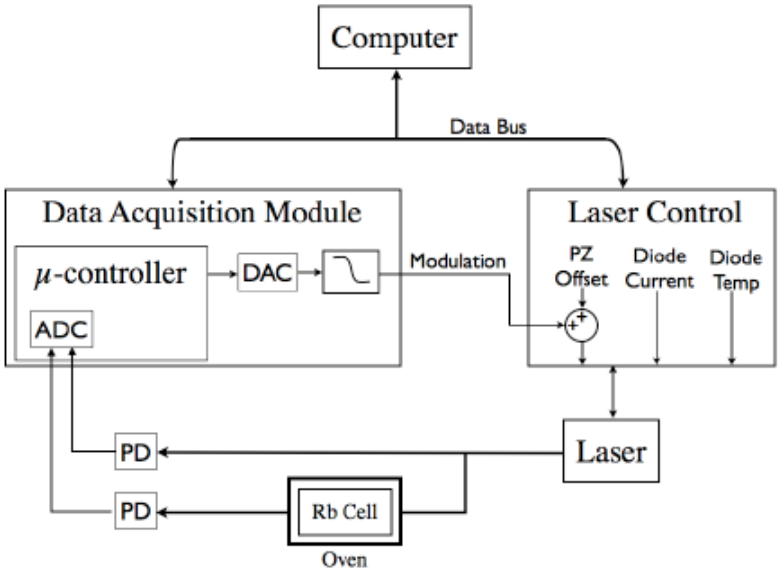


Figure 2. *A block diagram of the instrument and experimental setup. A computer is connected to the laser control module and the data acquisition module via serial cables. The data acquisition module is connected to two photo-diodes for a reference and a probe laser beam. A signal generator output is connected from the data acquisition module to the laser control module for modulating the piezo voltage.*

Mode-hopping appears as abrupt jumps in laser intensity. It was noticed in early measurements with this system that the power spectrum of data taken under multi-mode operation exhibited much larger high frequency components. A method was thus developed which quantities the amount of mode-hopping by summing all non-zero frequency components in the power spectrum of a raw data signal. The process of computing a power spectrum from time series data and summing the non-zero components uses modest computing resources and could be executed in a functional module, but is currently executed by the control-computer.

Figure 3. *Wavelength control instrumentation and experimental setup*

The modulation signal frequency is chosen to be greater than 150 Hz to allow sufficient low pass filtering of line noise while still being slow enough to avoid imposing unnecessary stress on the mechanical assembly which is audible at 1000Hz.

The sampling speed requirement is set by one of the experiments which requires resolution of features narrower than $1/20^{th}$ of the waveform period. At 150 Hz, such a feature exists for approximately 333 μs. If the feature is sampled with at least five data points, the sampling rate must be greater than 15 kHz.

Wavelength locking requires the instrument to be able to modulate the laser wavelength and correlate the detected signal with a phase-shifted signal at the same frequency as the modulation. The modulation signal is a triangle wave which is converted to a voltage and applied to the piezo. A sinusoidal modulation may place less mechanical stress on the laser assembly, but the linearity of a triangle wave is assumed to provide a more reliable probe of the absorption line.

The cross-correlation is performed by multiplying the detected signal with a square wave phase-shifted 90 from the triangle wave in the modulation signal as illustrated in Figure 4. Weel and Kumarakrishnan[4] identified a square wave as the signal which produces the highest signal to noise when computing the cross-correlation. This was not independently verified. The data acquisition module is responsible for producing the modulation signal so that the phase is well known when signal data are acquired. A square wave is used as the cross-correlation signal in order to simplify computation. Each sampled point must be associated with the phase of the square wave at that point in time. The simplicity of a square wave means that only the quadrant of the waveform needs to be captured.

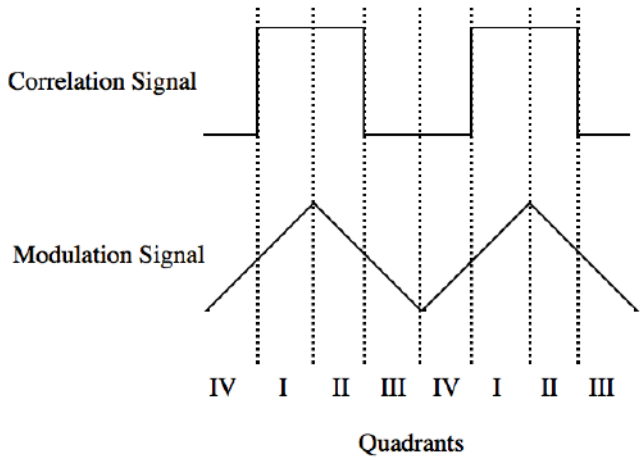


Figure 4. *The modulation signal is a triangle wave. The cross-correlation is performed by multiplying the detected signal with a square wave at the same frequency as the modulation signal and a 90° phase shift. Computing the cross correlation digitally only requires the quadrant of the modulation waveform to be associated with each sampled point.*

[4] M. Weel and A. Kumarakrishnan. *"Laser-frequency stabilization using a lock-in amplifier,"* **Can. J. Phys,** Vol. 80, pp. 1449-1458, 2002.

Each data set collected with the instrument contains detailed metadata describing the experimental conditions and laser parameters. Meta-data are heavily used in data-analysis and post-processing and reduce the amount of experimental information which must be collected manually.

A scripting interface was specified so that experimental runs can be programmatically executed under computer control. The scripting language provides access to serial communication ports and excellent integration with the file system so that data are easily manipulated. A cross platform scripting language was selected so that the control computer operating system is not relevant.

See the full thesis[3] for the technical specifications of the hardware and software used in these experiments.

3. Results

This section presents results from data acquired with the modular instrument. An attempt was made to map the wavelength and mode instabilities of an ECDL. From these data it may be possible to design a wavelength locking control algorithm which allows a user control over laser power output while avoiding mode-hopping. The experimental setups and data processing steps are presented along with results. Closed loop wavelength locking to a Rb D2 line is demonstrated and a number of important observations are made that may contribute to an improved control algorithm.

Maximizing the attenuation of laser light in a rubidium vapor cell will maximize the amount of pump light absorbed by the DPAL. The attenuation is computed by dividing the measured intensity of a probe beam passing through the vapor cell with a reference beam. Figure 5 shows a data set where the laser crossed through a mode hop at 3 V and the wavelength abruptly changed.

It was realized early on that these mode hops were problematic when attempting to lock the wavelength to an absorption peak. Consider a feedback loop attempting to drive the wavelength to a reference point at the maximum of an absorption line. If the laser was on the wrong side of a mode-hop, for instance at the 5 Volt position in Figure 5, it will incorrectly identify the mode-hop as the peak of the function. A robust control must therefore not only be able to drive the laser to the peak of an absorption feature, but be able to identify false peaks due to mode-hops.

These data scans can be extended to a two-dimensional grid of diode current I_d, and piezo voltage V_p Data were acquired at each point in a dense $[I_d; V_p]$ grid by first by increasing current at fixed piezo voltage, then incrementing the piezo-voltage, and then decreasing current.

Figure 6 presents the results of the attenuation scan over a portion of the $[I_d; V_p]$ grid as a gray scale map with I_d and V_p along the x and y axis and color representing attenuation. A strong periodicity was apparent inthe y direction. However, because adjacent rows represent scans in

opposite current directions, the rows can be de-interlaced to produce two images, one for an upward current direction and one for a downward current direction. Figure 7 shows the result of de-interlacing the two-dimensional data.

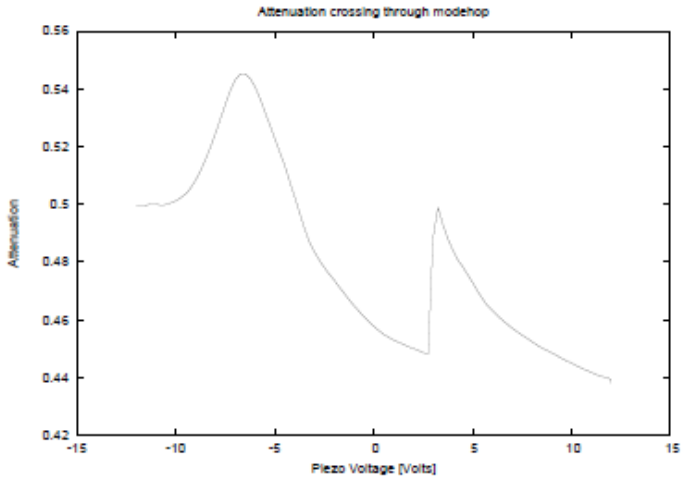


Figure 5. *Absorption measurement of atomic rubidium vapor in the presence of mode-hopping. The laser crosses a mode-hop and the wavelength abruptly changes jumping the power to a different region of the absorption line.*

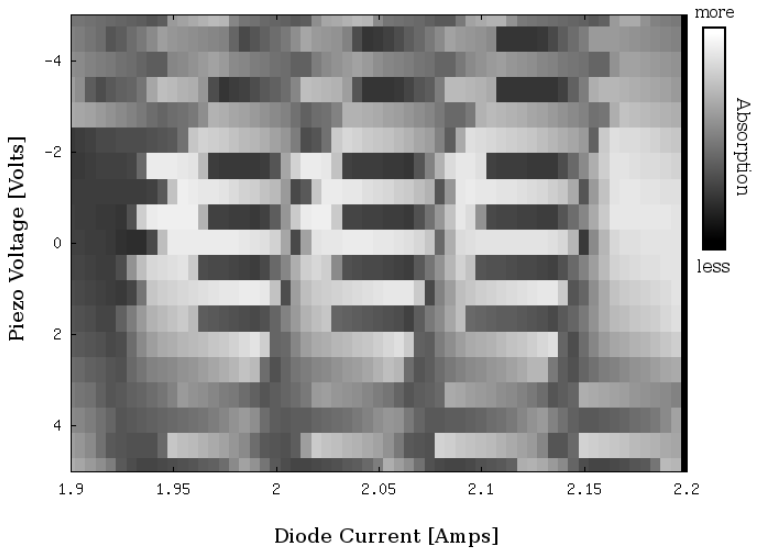
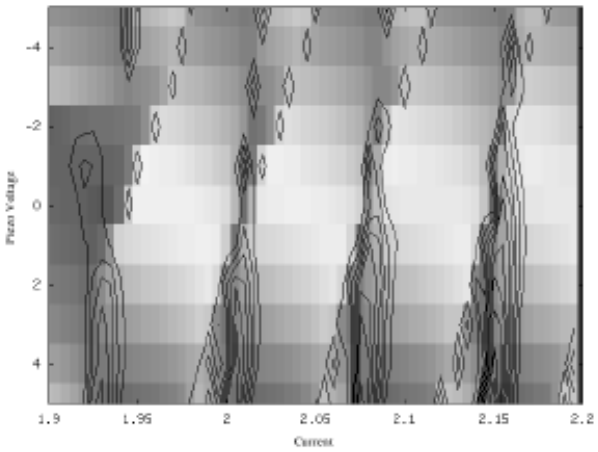
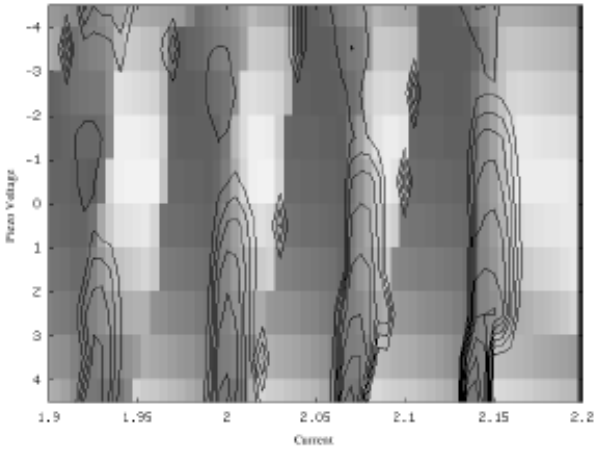


Figure 6. *Map of attenuation over [I_d; V_p] grid. The strong periodicity along the y-axis can be explained by the effect of changing current direction.*



(a) Increasing Current.



(b) Decreasing Current.

Figure 7. *Absorption, gray scale, and mode-hopping, contours, over a grid of piezo voltage and diode current. Higher absorption is white, lower absorption is black. Two images from single scan, de-interlaced based on current direction.*

Closed loop control of the ECDL wavelength was implemented by executing a script on the control computer which forked an independent thread and executed a sequence of commands repeatedly until stopped by the user.

Figure 8 presents data from 180 seconds of closed loop control in the presence of mode-hopping with the same alkali cell as above. The initial conditions were I_d = 2:115 Amps, V_p = 2:991 Volts. The laser was disturbed at 60 seconds by decreasing the current by 45mA to 2.07A until the generated error signal became noisy. At that point, the attenuation dropped and the noise power more than quadrupled. While in this mode-hopping region, the attenuation was decreased but the generated error signal centered on zero, giving credence to the earlier statement that the controller would find a false absorption maximum located on top of a modehop. At 120 seconds, the current was decreased by 70mA to 2.0 Amps. A sharp drop in attenuation indicates the wavelength crossed through a severe mode-hopping region. Some mode hopping is still evident at the new current as indicated by slightly elevated noise power and

higher noise in the error signal, although attenuation is comparable to that at the start. This scenario demonstrated that closed loop control of laser wavelength is possible and stable, but, in the presence of mode-hopping the absorption of pump light decreases.

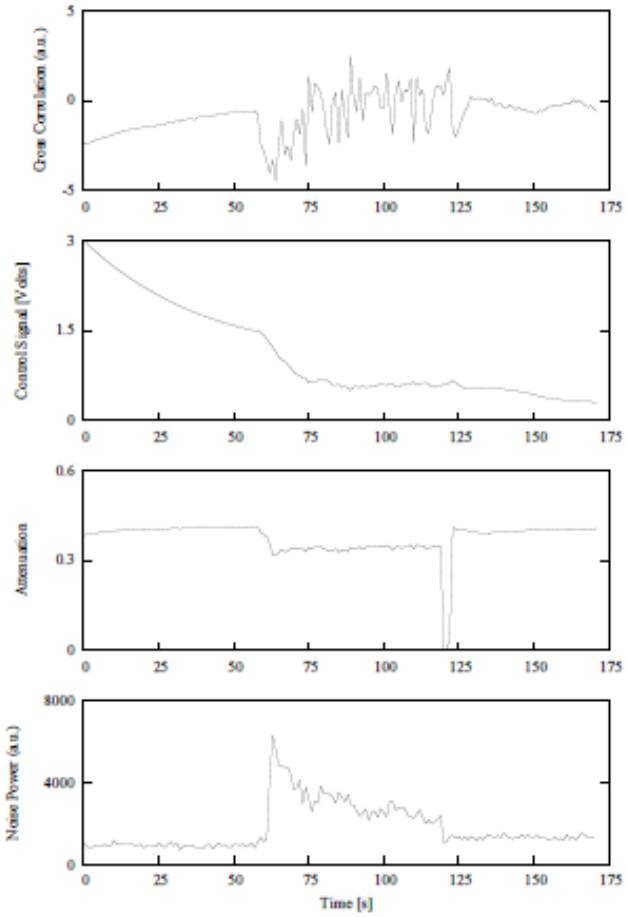


Figure 8. *Error, control voltage, attenuation and noise power for 180 seconds of closed loop control. The laser was intentionally driven to a mode-hop region at 60 seconds by adjusting the current. The generated error and attenuation exhibit increased signal noise and the total noise power increases substantially. At 120 seconds the system was disturbed again. The noise levels remain elevated, but the attenuation is comparable to the beginning third of the data.*

4. Conclusion

This project began as an effort to improve and enhance data fidelity and to develop a control system for a DPAL in order to improve reliable DPAL operation. At the beginning of the project mode-hopping was observed and identified as a problem, but it was not clear how to correct or avoid it. This thesis presented a smart instrument capable of high fidelity data acquisition to map the wavelength and mode-hopping of a diode laser. The maps revealed combinations of diode current and grating angle which result in stable diode laser operation.

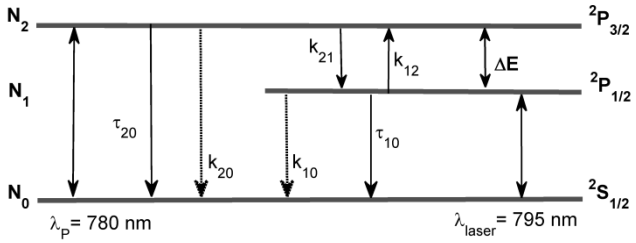
III. UNM Student - Nathan Zameroski

Nate Zameroski was the first UNM grant student admitted to candidacy for the PhD degree in Electrical Engineering (Optoelectronics) at the University of New Mexico. He has now completed all course work and his dissertation proposal defense entitled *"Radiation trapping and quenching of rubidium fluorescence."* His university advisor is Dr. Wolfgang Rudolph of the Physics and Astronomy Department. He anticipates graduation in June 2011. His research progress is summarized below.

Introduction

The topic of this research is Diode Pumped Alkali metal vapor Laser (DPALs). These laser systems were proposed by Krupke[5] in 2003 and since that time, these systems have received considerable interest[6,7] as ways to develop high power lasers. DPALs have been demonstrated with potassium (K), rubidium (Rb), and cesium (Cs) which have lasing wavelengths in the near-infared region of ~ 770, 795 and 895 nm respectively. These laser wavelengths fall within an atmospheric transmission window and DPALs thus could potentially be used for a variety of military applications.

DPALs are three-level lasers which are pumped on the D2 transition, $^2S_{1/2} \rightarrow {}^2P_{3/2}$, and support lasing on the D1 transition, $^2P_{1/2} \rightarrow {}^2S_{1/2}$. Figure 1 shows the energy level diagram for the Rb DPAL. The energy difference ΔE between the $^2P_{3/2}$ and $^2P_{1/2}$ states for Rb is ~ 237 cm^{-1} and this small energy defect leads to intrinsic quantum efficiencies of greater than 98% and to the possibility of very efficient laser systems. An important challenge for DPAL technology is



[5] W.F. Krupke, "Diode pumped alkali lasers (DPALs) and Amplifiers (DPAAs) with reduced buffer gas pressures", US patent, Patent No. 7,061,958 B2, (2003).
[6] J. Zweiback and W.F. Krupke, "High power diode pumped alkali vapor lasers," High-Power Laser Ablation VII **Proc. of SPIE,** Vol. 7005 700525 (2008).
[7] B.V. Zhdanov and R. J. Knize, "Alkali lasers development at Laser and Optics Research Center of U.S. Air Force Academy," **Proc. of SPIE,** Vol. 7005 No. 700524-1, (2008).

Figure 1. *Energy level diagram of rubidium. Also shown are the pump and laser transitions, the collisional mixing rates (k_{21} and k_{12}), quenching rates (k_{20} and k_{10}), and spontaneous emission lifetimes (τ_{20}=26.2 ns and τ_{10}=27.7 ns). ΔE = 237.6 cm^{-1}*

that of matching the pump diode bandwidth to the width of the gas phase absorption profile. This may require pressure broadening of the absorption line shape, narrowing of the laser diode bandwidth, or a combination of both.

In a majority of the reported experimental studies, rapid spin-orbit relaxation with an additive gas (buffer gas) such as methane or ethane, typically at a pressure of several hundred Torr, populates the lower $^2P_{1/2}$ state. Efficient laser operation requires several hundred Torr of the additive gas in order to make the time constant for relaxation between the spin-orbit states much faster than their spontaneous radiative lifetimes, (~27 ns for both spin-orbit states of Rb). Collisional relaxation between the $^2P_{3/2}$ and $^2P_{1/2}$ levels is an essential part of the lasing kinetics (this process is also referred to as spin orbit mixing). This step releases heat into the laser medium. Despite the relatively small energy spacing between the alkali metal ^2P components, the release of heat from spin-orbit relaxation is significant, even for pump powers as low as 30 W [7]. Electronic quenching (e.g., $Rb(^2P_J)+X \rightarrow Rb(^2S_{1/2})+X$) releases far more energy per occurrence than the spin orbit mixing process and is therefore a potential source of additional heat. As the technology moves forward to higher power devices, precise information on the quenching behavior will be critical for the design of the laser thermal control system.

Research Goals

The focus of this research is on the Rb DPAL and underlying physics which govern these devices. Two specific problems/challenges that Rb DPAL technology faces were addressed by using a variety of experimental techniques and theoretical calculations. These challenges were: (1) determine precise values of Rb-buffer gas quenching cross sections, and (2) measure the pressure broadening and collisional shift rates of Rb with various buffer gases. The next two sections will briefly describe the experimental techniques and show some of the experimental results for measurements of the Rb-buffer quenching cross sections and the pressure broadening and collisional shift rates of Rb with various buffer gases.

Quenching Cross Section Measurements

There have been previous studies on the kinetics of mixing and quenching of the upper P level states of Rb with methane and ethane as collision partners.[8,9] These studies used fluorescence intensity measurements of the D1 and D2 transitions to determine mixing and

[8] E.S. Hrychyshyn and L. Krasue, "Inelastic collisions between excited alkali atoms and molecules. VII. Sensitized fluorescence and quenching in mixtures of rubidium with H2, HD, D2, N2, CH4, CD4, C2H4, and C2.H6," **Canadian J. Phys**., Vol. 48, 2761 (1970).

[9] B. R. N. Bulos, "Collisional Relaxation of Excited State Alkali Atoms," **Pure Science**, Columbia, (1972).

quenching cross section values. Examination of the quenching cross-section values from previous measurements show that agreement is reasonable; however, the error bands especially for the results of reference [8,9] are nearly as large as the reported values indicating a considerable uncertainty in these values. In addition to the uncertainties in the quenching cross section values associated with fluorescence intensity measurements, Rb DPALs laser experiments indicated that the quenching cross sections appear much smaller than those reported in [8,9]. The experimental laser data[6,10] does not directly measure nor can it be used to quantify quenching cross-sections. However, it has suggested the need, given the importance of these parameters to future alkali metal laser development, to re-examine the quenching kinetics of Rb by collisions with buffer gases. This research re-measured the quenching cross sections of Rb wth methane and ethane and reported [2] on values almost two orders of magnitude smaller than in [6,7] by using time resolved fluorescence spectroscopy and the experimental set-up shown in Fgure 2.

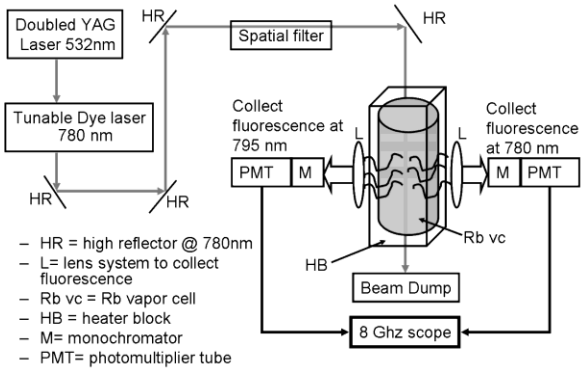


Figure 2. *Experimental set-up for measuring quenching rates/cross sections of rubidium with different buffer gases.*

The experimental approach for measuring Rb-buffer quenching cross section is described as follows: a sealed Rb vapor cell (quartz) with know buffer gas number density (pressure) is excited on the D2 absorption line (780 nm) and the emitted D1 fluorescence (795 nm) is measured and recorded by a PMT connected to a digital oscilloscope. By measuring the temporal decay of the D1 fluorescence for various buffer gas pressures and Rb vapor cell temperatures, the quenching cross section can be extracted. A concern with this temporal resolved measurement is the effect of radiation trapping, the absorption and re-emission of resonant photons in the Rb vapor. This process must be taken into account for the determination of the quenching cross sections as it lengthens the temporal decay of the emitted fluorescence from its natural lifetime or decay rate. Quenching on the other hand shortens the temporal decay of the emitted fluorescence from its natural lifetime or decay rate. These competing processes can be theoretically described by the Holstein rate equation and its solutions, which was numerical implemented to aide in the analysis of experimental results.

[10] T.A. Perschbacher et al., "High-efficiency diode-pumped rubidium laser: experimental results," XVI Int. Symp. on Gas Flow, Chemical Lasers, and High-Power Lasers, **Proc. of SPIE** Vol. 6346, 634607, (2007).

Figure 3 shows the affects of radiation trapping on the fluorescence emitted from the D1 line for a Rb cell containing 500 Torr of methane. This figure shows that as the temperature of the Rb-methane vapor cell is increased, the emitted fluorescence takes long to decay. The affect is due to radiation trapping, the absorption and re-emission of resonant photons in the atomic vapor. Basically, increasing the cell temperature increases the number density of Rb atoms in the gas phase and the probability that a photon is absorbed and re-emitted before escaping the vapor cell, thus lengthening it temporal decay.

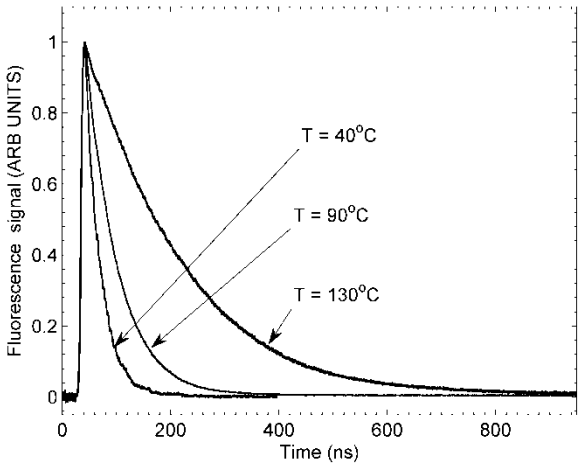


Figure 3. *Normalized measured D1 fluorescence waveforms from the 500 Torr Rb-methane cell at 40 °C, 90 °C and 130 °C.*

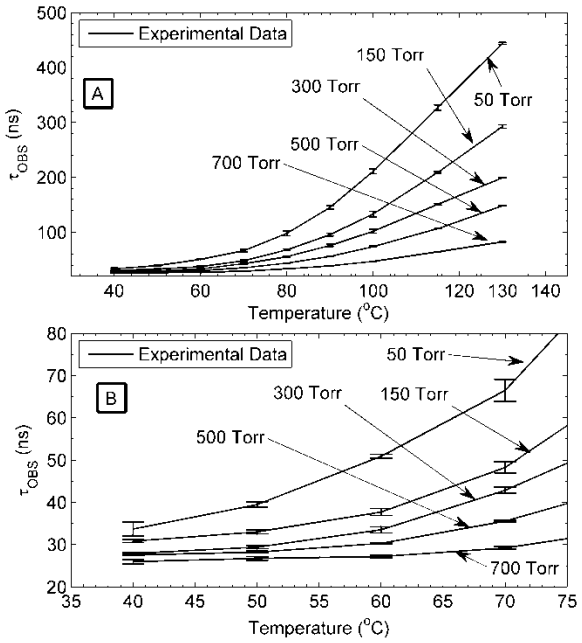


Figure 4. *The effective trapped observed lifetime (τ_{OBS}) values of Rb D1 fluorescence vs. temperature for methane pressure of 50, 150, 300, 500 and 700 Torr for a temperature range of (A) 40 ^{o}C -130 ^{o}C and (B) 40 ^{o}C - 75^{o}C.*

Figure 4 shows the effective trapped observed lifetime (τ_{OBS}) values of Rb D1 fluorescence vs. temperature for several methane pressures. These plots indicate that methane does not quench. For all pressures the measured τ_{OBS} at 40 °C is approximately the radiative lifetime of ~ 27 ns. If quenching occurred to any significance, τ_{OBS} would be on the order of a few ns.

Similar data was obtained for Rb-ethane. The upper bounds of the quenching cross-section values for methane and ethane derived from the quenching experiments at 40 °C are $\sigma \leq 0.019$ Å^2 and $\sigma \leq 0.033$ Å^2, respectively.

Section 2 - Pressure broadening and shift measurements

The pressure broadening and shift rates of the alkali metals with buffer gases have been investigated thoroughly over the past few decades[11,12]. However, gaps remain in the literature for some of the buffer gases of interest to the Rb DPAL community. Specifically, the broadening and shift rate of Rb by ethane is unknown and is important for modeling the Rb D2 absorption line. In Figure 5, the experimental set-up used to measure the Rb D2 line broadening and shift by ethane and other hydrocarbon gases is shown.

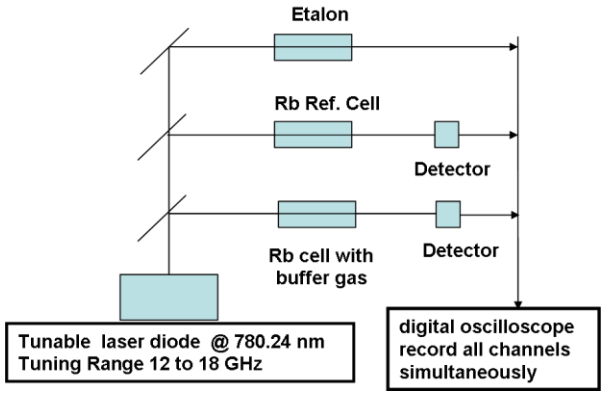


Figure 5. *Experimental set-up for measuring pressure broadening rates of Rubidium with various buffer gases.*

[11]N. Allard and J. Kielkopf, "The effect of neutral non resonant collisions on atomic spectral lines," **Rev. Mod. Phys.** Vol. 54, 1103 (1982).
[12]W.R. Hindmarsh and J.M. Farr, "Collision broadening of spectral lines by neutral atoms," **Prog. Quantum Electron.** Vol. 2, 141 (1972).

The basic approach for measuring broadening and shift rates is described as follows; A tunable diode laser at ~780 nm is split into three beam lines as shown in Figure 5. One beam line contains a 300 MHz etalon that acts as a frequency ruler. The second beam line contains a Rb reference cell (low pressure 2-5 mtorr) for absolute frequency reference and the third beam line contains a Rb cell with known buffer gas pressure. The tunable laser diode is scanned over the Rb D2 absorption transition of both cells and the spectra recorded along with the etalon trace. The broadening and shift rates can be found by measuring the Rb D2 line absorption spectra as a function of buffer gas pressure. A sample of the measured oscilloscope signals for each of the three beam lines (Figure 5) is shown in Figure 6.

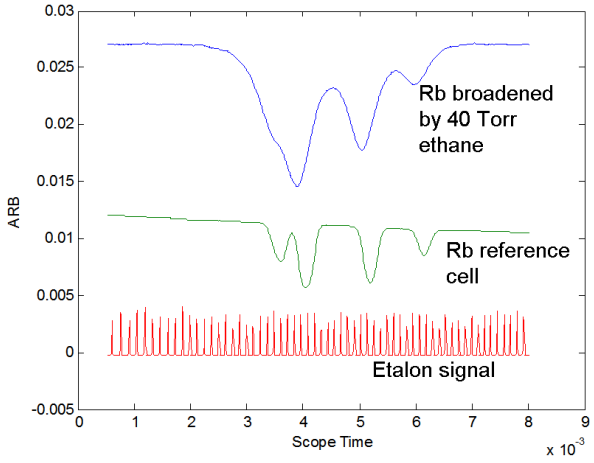


Figure 6. *Measured waveforms from pressure broadening experiments.*

In Figure 7, the measured pressure broadened Lorentzian width $\Delta\nu_L$ (FWHM) and shift Δ are shown versus methane and ethane pressure. The pressure broadening and shift rates are extracted through linear fits of the experimental data. The Rb-methane broadening rate is 28.0 MHz/Torr and the shift rate is -8.4 MHz/Torr (7A and 7B respectively). These values are in agreement with current literature values.[13] The broadening and shift rates obtained for Rb-ethane (7C and 7D) are 28.1 MHz/Torr and -8.8 MHz/Torr respectively.

In Figure 8 A & B, the pressure broadening and shift rates of several hydrocarbon gases [methane (CH_4), ethane (C_2H_6), propane (C_3H_8) and n-butane (n-C_4H_{10})] gases are plotted versus their ground state dipole polarizability. We find that for these particular hydrocarbon gases, linear relationships exist between the broadening and shift rates with polarizability. Theoretical calculations using existing pressure broadening theory [11,12] also show a linear dependence of the broadening and shift rates of these hydrocarbon gases versus their ground state dipole polarizability. The theoretical broadening rates of the Rb D2 absorption line for CH_4, C_2H_6, C_3H_8, n-C_4H_{10} are 23.3, 24.9, 26.4, and 27.8 MHz/Torr, respectively. The corresponding shift

[13] M. D. Rotondaro and G. Perram, "Collisional broadening and shift of the rubidium D1 and D2 lines (52S1/2 → 52P1/2, 52P3/2) by rare gases, H_2, D_2, N_2, CH_4 and CF_4," **J. Quant. Spectrosc. Radiat. Transf.** Vol. 57, 497 (1997).

rates are -8.4, -9.0, -9.6, and -10.1 MHz/Torr, respectively. The measured broadening rates γ_B of CH_4, C_2H_6, C_3H_8, and n-C_4H_{10} are 28.0, 28.1, 30.5 and 31.3 (MHz/Torr), respectively. The corresponding shift rates γ_S are -8.4, -8.8, -9.7, and -10.0 (MHz/Torr), respectively. There is reasonable agreement between the measured and theoretical rates.

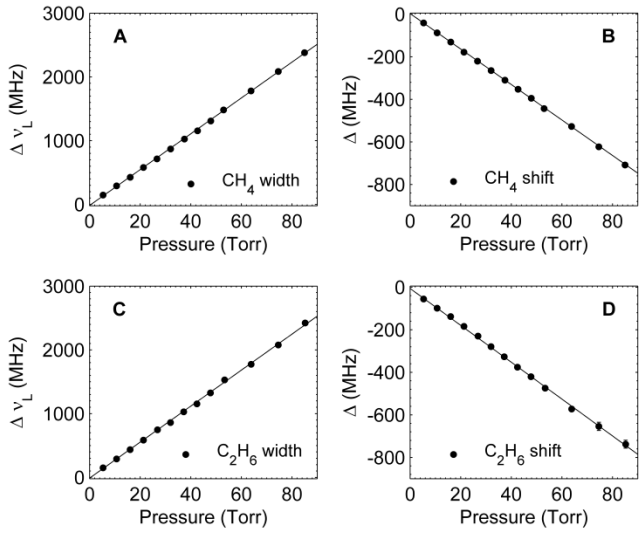


Figure 7. *Lorentzian line width $\Delta\nu_L$ and shift Δ of the Rb D2 transition obtained from measured absorption spectra as a function of methane (CH_4) and ethane (C_2H_6) buffer gas pressure A&B and C&D respectively (T=314 K). Experimental data (dots ●), solid line is weighted linear fit.*

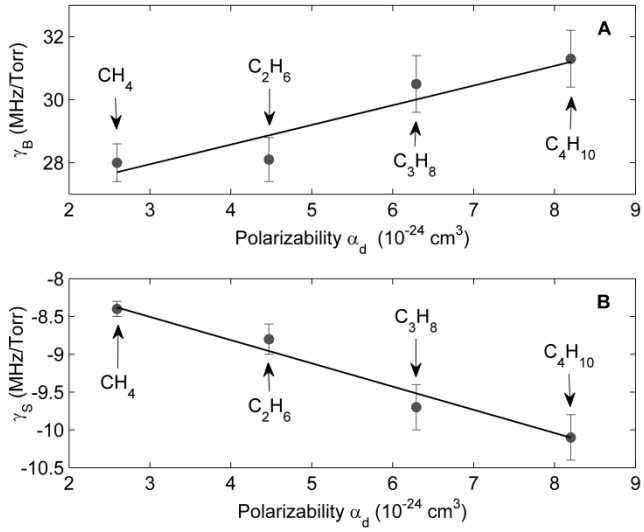


Figure 8. *Measured (dots ●) Rb D2 absorption line broadening and shift rates of hydrocarbon buffer gases vs. dipole polarizability, (A) and (B) respectively. Solid line in (A) and (B) represents a weighted linear fit of the data points.*

Future work

Current and on going research not presented or discussed in this summary will focus on experimental and theoretical studies of Rb-methane and other Rb-buffer gas laser systems. Experimental data will be used to benchmark and test pulsed laser models and make refinements in the model where necessary. In addition to the laser experiments and modeling, I plan to investigate thermal transients already observed in Rb-methane data. This thermal transient causes the output power of the Rb DPAL to fluctuate ~ 3 to 5% over a period of 10 to 30 seconds for a constant pump power. This affect depends on the Rb-methane cell conditions and pump laser conditions. The experimental laser studies and numerical modeling of the Rb-methane DPAL should hopefully lead to another publication.

IV. New Mexico Tech Student - Lindsay Quarrie

Lindsay Quarrie's dissertation topic for his PhD at NMT is "Atomic Alkali Resistant Optical Thin Film Coatings." His proposed research, if successful, will provide the Air Force with a clear path towards engineering practical DPALs systems for future missions. Mr. Quarrie's advisor is Professor Scott Teare. He expects to graduate in the summer of 2011.

Problem

Hybrid lasers using diode pumped atomic alkali gain medium have been developed in recent years that combines an electrical semiconductor diode laser with a gas/chemical laser to achieve efficiencies much higher than a chemical/gas or a solid state laser. These type of hybrid lasers are known as diode pumped alkali lasers or (DPALs). Although they have improved efficiency, cost and size some technical issues still need to be solved before this high efficiency laser is scalable to a kilowatt class system. Currently, the optical windows of the gain medium are eroded by the atomic alkali, negatively affecting the optical performance and output power of the laser. Often the laser is destroyed, with costly consequences in safety, maintenance and operation. Mr. Quarrie has proposed to conduct research that will evaluate commercially available optical quality crystals and thin film coatings with suitable refractive index matching as a non-reactive and inert barrier against atomic alkali to solve this problem for the Air Force. The research is to obtain a fundamental understanding of the degradation mechanisms in DPAL gain cells, in order to determine a means of minimizing the damage to the optical windows in the gain cell while maximizing optical pump efficiency.

Experiment

A controlled DPAL environment was created as shown in Figure 1. A no flow laser /possibly a flow test head may be necessary to purge and evacuate the alkali after test period to avoid atomic alkali clinging to the surface of the witness samples after cooling. The following are some of the main features of the system:

1. The ability to insert rubidium easily into the gain cell;
2. Oven capable of heating the gain cell to 200 degree Celsius alkali temperature;
3. Helium buffer gas to alkali concentration He:Rb of the order of 6:1;
4. Alkali pressures of 5-20 millitorr;
5. Alkali number density of 3-5 x 10^{13} /cm^3.

Thin film coatings of selected materials will be applied uniformly over the surface area of individual test coupons and placed in the gain medium. The first experiment will be to introduce alkali resistant materials test coatings into the gain medium to observe any degradation caused by the atomic alkali vapor.

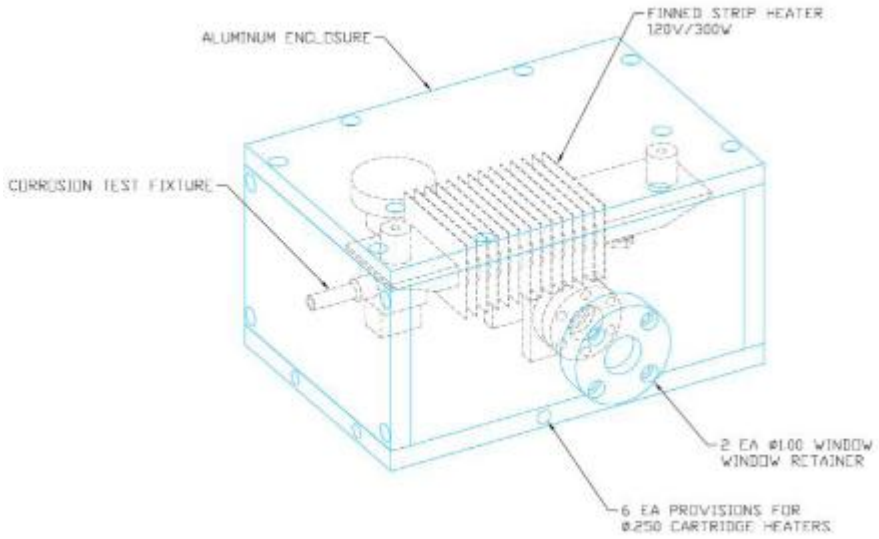


Figure 1. *Assembled DPAL alkali environment test fixture*

Twelve (12) witness sample substrates of 12.7 mm or less in diameter will be prepared from commercially available optical quality materials, one of which will be quartz. An additional three (3) witness samples will be control samples made from corrosion resistant and stress corrosion resistant austenitic stainless steel AL-6XN , 254SMO or the cheaper 316L or 304L. All witness samples will be coated, including control samples, with selected atomic alkali resistant coatings/thin films to cover the entire surface of the cylinders.

The following steps will be followed during the experiment to collect the data:

Step 1: Apply coating to substrate and control samples.

A few coatings/substrates will be selected from the list below using up to 12.7 mm diameter witness samples and selected coatings applied. These coatings/substrates are chosen for their optical quality, typical robustness and tendency to resist oxidation and corrosion except in the case of the control sample substrate being stainless steel alloy. The initial set of coating/substrates are Magnesium Fluoride (MgF_2), Calcium Fluoride (CaF_2), Hydrogen Free Tetrahedral amorphous (taC) diamond like carbon (DLC), Single Crystal Sapphire (Al_2O_3)/Synthetic Fused Silica/Fused Quartz, Zinc Sulfide (ZnS), Allyl Diglycol Carbonate (ADC)/Columbia Resin CR-39, Indium Titanium Oxide (ITO) and Hafnium Oxide (HfO).

Step 2: Apply hot alkali laser environment.

The coatings will be evaluated in iterative steps under the following exposure conditions:

Alkali → Alkali + Heat → Alkali + Heat + Laser.

A. Insert coated substrates into Alkali test module gain cell;

B. Place in oven, shown in Figure 2, with possible purge assembly and heat atomic alkali and Helium buffer gas up to 200°C;

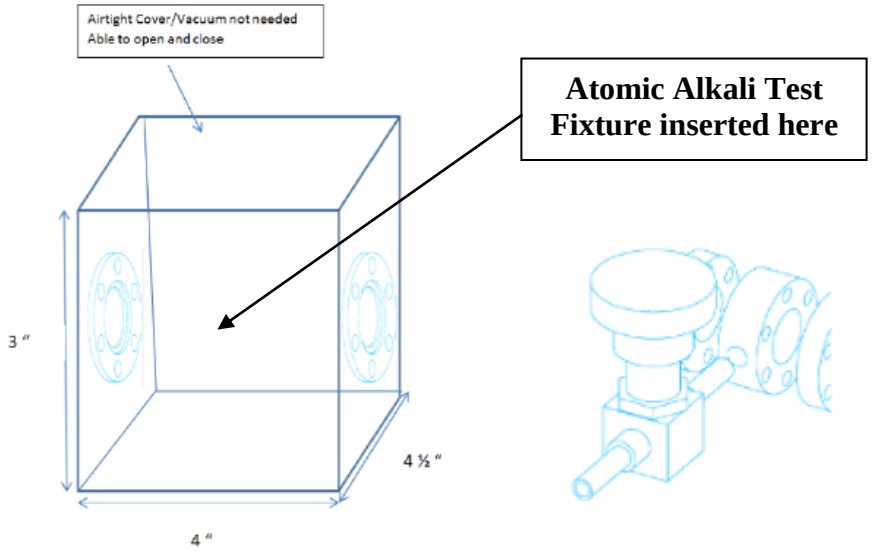


Figure 2. *Oven showing possible additional purge assembly to be attached, right.*

C. Turn on and fire the Ti: Sapphire pump laser (up to 1 kW/cm²) into the gain cell for one week.

Step 3. Testing and Analysis.

Witness samples will be tested and analyzed with the early elimination of samples that show reactions to the atomic alkali. The following are quick observations that can be made and are precursors to further analysis:

A. Visual Inspection. Did the coating go dark/change color? What visible defects exist?
B. Did Rubidium end up plating the coating?

Further analysis will consist primarily of examination for witness samples in stages before and then after exposure to the atomic alkali, heat and laser using a selection of the available tools for potential use:

C. Rockwell Hardness Tester, Rheometer (NMT) – hardness, stress on substrate/coating interface;

D. Non-contact Gaertner Spectroscopic Ellipsometer (UNM) – The witness samples will be positioned under the ellipsometer measuring thickness, absorption and refractive index of the witness sample.
E. Hirox KH7700 3D Digital Confocal Microscopy (NMT) – The witness samples will be positioned under the digital microscope for optical inspection, to note changes in color and any obvious defects before and after exposure stages to the atomic alkali.
F. Cameca SX-100 SEM inspection with elemental analysis (NMT)-The witness sample will be closely inspected for any changes in surface properties including elemental analysis and any surface reaction products of the thin film with the atomic alkali.
G. Milligram Weight Scale (AFRL)-The witness sample will be weighed to determine weight loss/gain before and after exposure of the witness sample to the atomic alkali.
H. LANL-Neutron Spectroscopy to observe reaction process.

Preliminary Results

The preliminary results of the optical power transmission experiments through witness samples will now be discussed. Wavefront sensing and beam profiles related to optical damage will be addressed in future experiments.

In the first experiment in which a 304L austentic stainless steel witness sample was exposed to the atomic alkali rubidium and heat, clearly there is interaction with the stainless steel witness samples. A significant average weight loss per sample was able to be detected. The chemical reaction likely produced reaction products involving Rubidium, Iron and Chromium (austentic stainless steel is coated with chromium for further protection). This experiment validates the method that will be used; that is, optical materials weights of witness samples will be measured before and after DPAL emulator insertion.

Significant changes in weight of the optical materials due to chemical reactions after exposure to atomic rubidium was shown to be detectable using a milligram or higher resolution weight scale. Weight changes is one of several correlating parameters related to the main broader parameter of interest in this experiment, which is the assessment of the optical damage to the witness sample due to the atomic alkali, heat and laser.

A clear method was, therefore, demonstrated by which the optical damage to the witness sample can readily be quantified by its optical power transmission losses.

Future Work

Future work includes introducing bulk crystal optical materials or thin film coated 12.5 mm diameter fused silica witness samples in "identical pairs" for experiments using wavefront sensing and beam profiling apparatus to look at the reference HeNe laser beam parameters. Then, exposure of one of the pair to alkali, heat and ~1kW/cm^2 intensity laser beam in stages over 7 days. The "twin" is returned to the optical measurement setup periodically to observe the degree of wavefront aberrations and any degradation of beam quality as a result of exposure to the atomic alkali, heat and pump laser compared the reference "twin" optical material. So far, nearly 30 optical materials have been identified for testing.

Beyond the UNM Grant

As a legacy student on this grant, Mr. Quarrie will be supported through a new grant from AFOSR to UNM. A new subaward will be generated from UNM to NMT giving him until the fall of 2011 to complete his dissertation.

V. UNM Student – Omar Qassim

Mr. Qassim is scheduled to finish his research on cesium dimer lasers in the summer of 2010. He is seeking his Masters Degree in Electrical Engineering and his advisor at UNM is Prof. Wolfgang Rudolph. His main goal is to determine if cesium dimer can be used as an alkali gain medium in high powered lasers. There are three main issues to investigate:

1. Find out if Cs2 can be a suitable gain material for alkali lasers;
2. Find a suitable enclosure that allows higher temps of 180 °C to be reached;
3. Find a solution to stopping the material from reaching the windows and corroding the anti-reflection coating.

There were four questions that were used to address the first issue:

- What is the optimal pumping wavelength?
- What will be the lasing wavelength(s)?
- What is the optimal Cs2 concentration?
- What is the minimum gain length required?

For these four questions experimental tests in the lab as well as calculations were done.

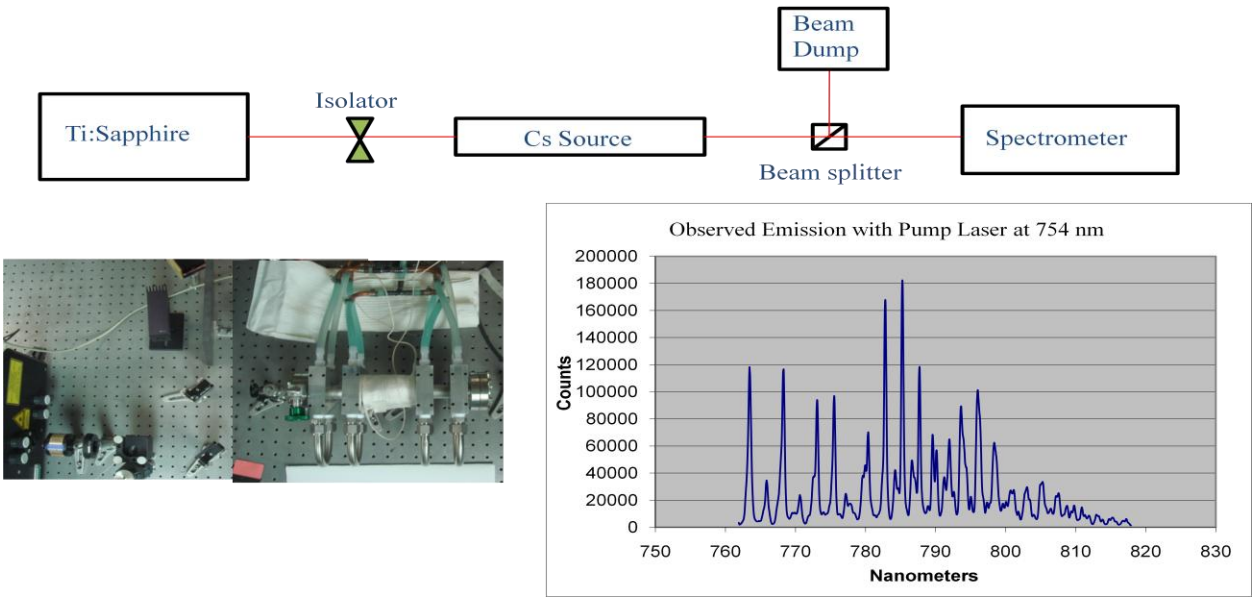


Figure 1. *Experimental setup and emission spectrum from Cs dimer laser*

Figure 1 shows the experimental set up for emission spectra from the cesium dimer. This test was done to determine the optimal pumping wavelength (first bullet above). Over 20 images of emission were recorded in a typical fluoresce measurement. A CW Ti:Sapphire laser beam is put through a cesium source. This source is a cesium glass cell with sapphire windows, and sits in a metal case with a thermocouple and heater rope on it. The cell is heated to about 240 °C to create these cesium dimers and the emission from these dimers go through the beam splitter to the spectrometer where their emission is recorded as can be seen in the graph. The extra Ti:Sapphire light that isn't absorbed by the cesium dimers is reflected in the beam splitter and goes to the beam dump. The results of these measurements gave potential pumping and lasing transitions that could be used for future experiments.

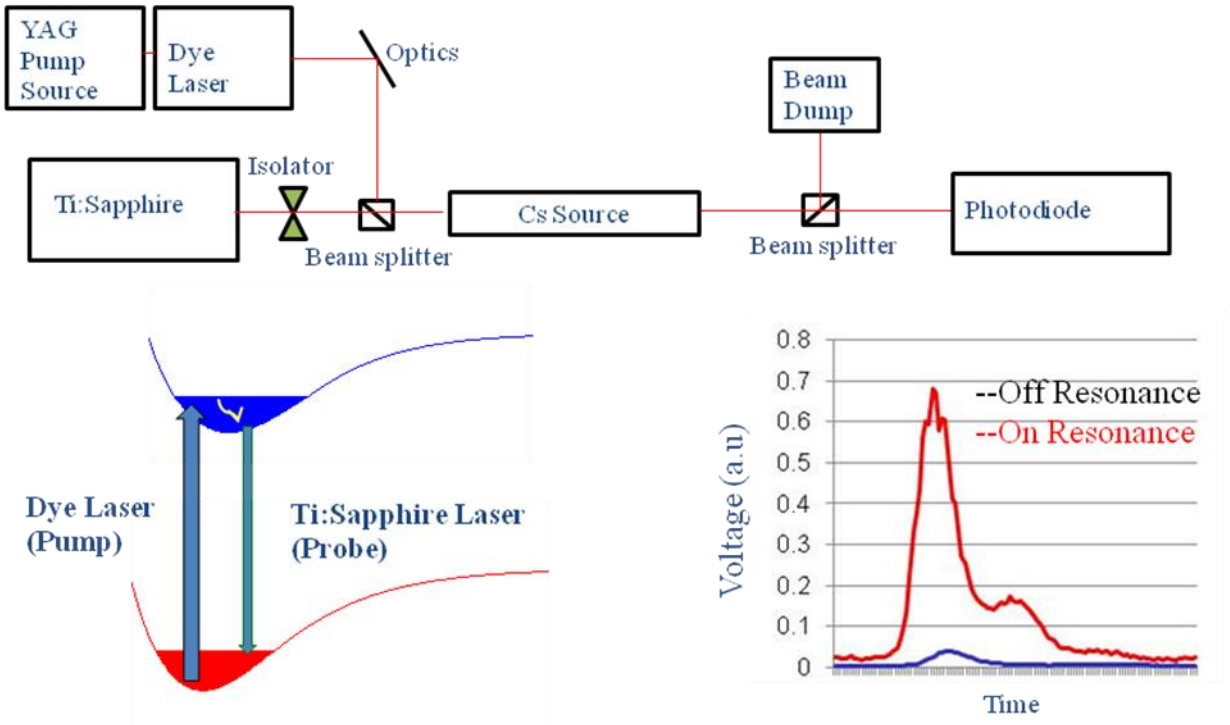


Figure 2. *Experimental apparatus for wavelength measurements and typical results*

Figure 2 is the experimental setup used to determine the lasing wavelength (second bullet above). It is a typical pump probe measurement setup. This arrangement was used to probe all the interesting transistions where gain should be detectable. The YAG pumped dye laser, a pulsed system, is sent through some optics that eventually reaches the cesium source. The source was described before and is the same for these measurements. The extra pulse laser light not absorbed is sent to the beam dump. The Ti:Sapphire laser goes through the same path as the YAG pumped dye laser through the cesium source and goes through the beam splitter to the photodiode. This photodiode is read by a oscilliscope. If attention is put on the pump probe diagram, it can be seen that the YAG pumped dye laser pumps the cesium dimer molecules from the ground state to an vibrational sublevel in the excited state. Then through rovibrational relaxation, the molecule relaxes a few levels quickly and then releases its excited energy at the

same transition the TI:sapphire laser is running. From there the dimer molecule rovibrationally relaxes back down to a ground state the YAG pumped dye laser can excite and the process repeats itself. In the bottom right picture, an output of what the oscilliscope would detect for both situations, the on resonance and off resonance. If the molecule releases its energy on the same wavelength of the TI:sapphire laser, we will see the red peak, and if it doesn't then the blue peak will be seen. It should be noted that the image in the bottom right is a simulation, not actual data collected from the photodetector. Although many transistions were probed, no gain was detected, however, multiphoton absorption was detected and this non-linear phenomeon might be the subject of future research in the upcoming months. There was no gain detection in this cesium dimer research because there were issues with keeping the temperatures and pressures stable. Although these results hinder further research with cesium dimer lasers at the current pump wavelengths (750-800 nm), this does not restrict further research in investigating other wavelengths of potential interest.

The container used to help solve the cesium corrosion and a higher temperature measurement is referred to as a heat pipe (see Figure 3). A quick overview of how it works will be presented. This new configuration can reach higher temperatures compared to the previous glass cell. The heat pipe is heated in the center hot enough to create a cesium vapor in the middle as the vapor travels out, it is attracted to the cool walls at the end of the heat pipe. As the cesium condensates on the wick, the cesium liquid starts to go back to the middle due to capillary action, and the process is cycled over and over. This heat pipe can take the cesium to temperatures over 375 °C compared to 230 °C of the older glass cells. With the cooling blocks on the ends, this also keeps the cesium from reaching the antireflective coating on the windows and corroding them.

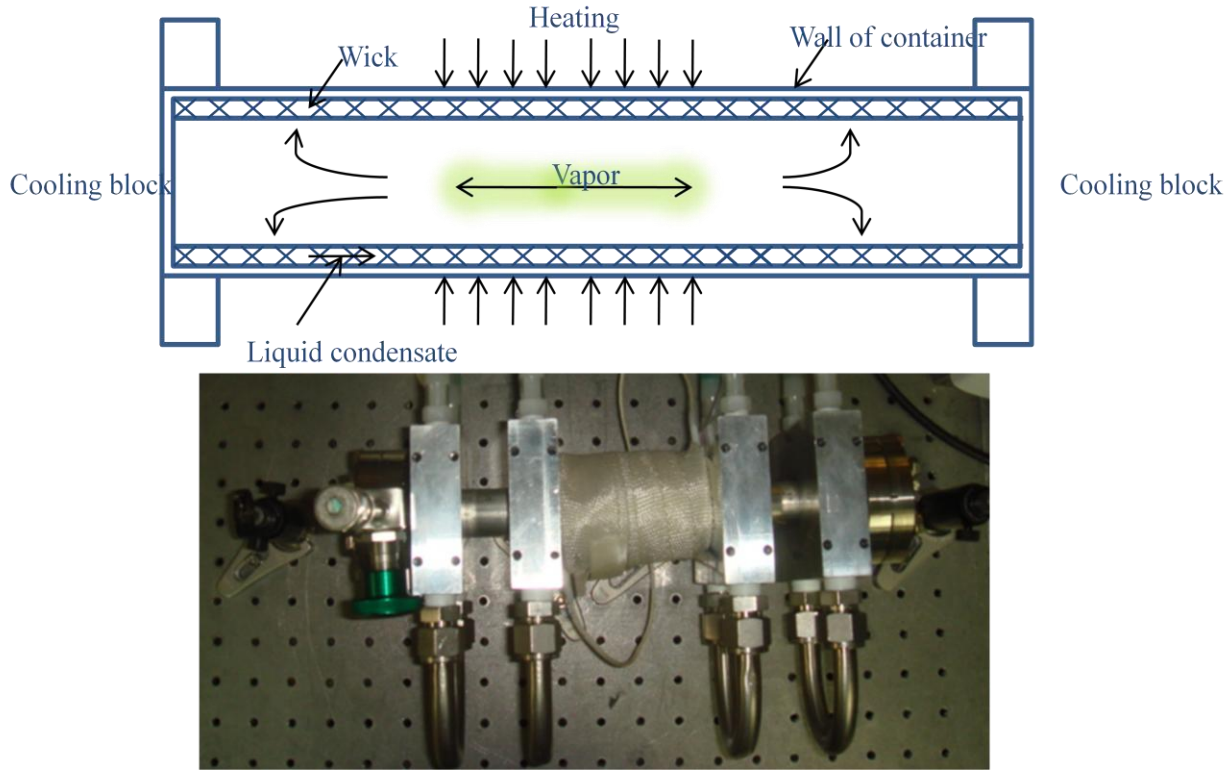


Figure 3. *Heat pipe for corrosion measurements*

All of this research is important to the Air Force because they are currently searching for new ways of creating a much more efficient laser for high power capabilities. Since alkali lasers have been shown to be some of the most efficient lasers around, research is currently being pushed to have these lasers become the next type of high powered lasers for military use. Much of this current research is the beginning stepping stones of research, where prototypes and a final deliverable product is still in the future.

VI. UNM Student – Nishant Patel

Nishant Patel is a PhD student at UNM in the Electrical and Computer Engineering Department with an Applied Electromagnetics Concentration (Plasma Physics emphasis). His advisor is Professor Luke Lester. He has completed two of his four comprehensive examinations required to graduate. His thesis topic is temperature insensitive double tunnel injection DWELL (quantum dots in-a-well) semiconductor lasers at 976 nm.

Importance of Research to AFRL and Research Goals

Currently, major research efforts are being undertaken to scale the output power of optically-pumped fiber amplifiers, emitting at 1064 nm to the many kW level. The cooling requirement of pump laser diodes sources used in these systems embodies a significant power footprint., Additionally, these cooling requirements for system efficiency impact space and weight requirements especially when the application involves a limited platform such as an aircraft. Thus, providing un-cooled pump laser diodes is of significant interest to AFRL. Successful completion of this research project will make significant progress towards reducing the power and size/weight requirements of the overall system.

The research goal of this study is to develop a novel semiconductor laser which emits at 976 nm while maintaining a high wall-plug efficiency over a broad temperature range. Laser emission at this wavelength is suitable for pumping Yb^{3+} doped fiber amplifiers. Figure 1 shows the absorption/emission spectrum of Yb^{3+} where the domainant absorption resonance is evident at 976 nm.

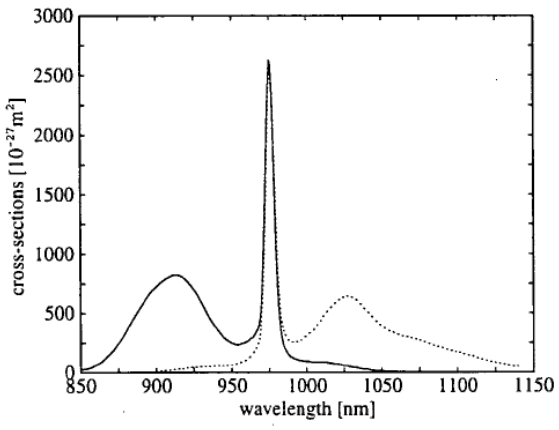


Figure 1. *Absorption (solid line) and emission (dotted) cross sections of Yb in germanosilicate glass.*

The current 976 nm laser pump diodes employed are strongly temperature dependent requiring an integrated water cooling system to ensure sustained performance. The additional power footprint of this cooling element hampers the overall efficiency of the amplifier system. Furthermore, the absorption line of Yb^{3+} in silica glass at 976 nm is only 5 nm at FWHM, as seen in Figure 1. Furthermore, gain in a semiconductor laser is a strong function of wavelength

and falls off abruptly at shorter wavelengths at finite current bias. With increasing temperature the lasing wavelength shifts to longer wavelength, resulting in the original lasing wavelength experiencing a reduction in gain. One solution to improving the temperature performance is to broaden the gain spectrum, which reduces the wavelength shift. Two types of active regions that can be employed to inhomogeneously broaden the gain spectrum are chirped multiple quantum well (MQW) or quantum dot (QD) structures. With respect to the QD structures, we have looked at gain as a function of temperature for 6, 8, and 10 stack InAs quantum dots in-a-well (DWELL) active regions as well for comparison purposes.

Experimental Setup and Data

L-I curve measurements:

As a proof of concept, a chirped MQW multi-section semiconductor device from Zia Laser (Wafer 1071G) that emits at 985 nm was examined. First, the L-I curve for this device was studied for a temperature range of 20-70 °C. The data was taken using a Labsphere integrating sphere and placed as close as possible to the emitting facet to maximize light collection. Figure 2 shows the results and it is clear that after 50 °C the device starts to degrade in performance since there is a large jump in threshold current versus the jumps in current threshold from 20-40 °C. Table 1 shows the slope efficiency for the L-I curves at each temperature. This baseline epitaxial design clearly does not meet the goals of the research, but it does provide a baseline for comparison in determining the standard temperature variation of the laser.

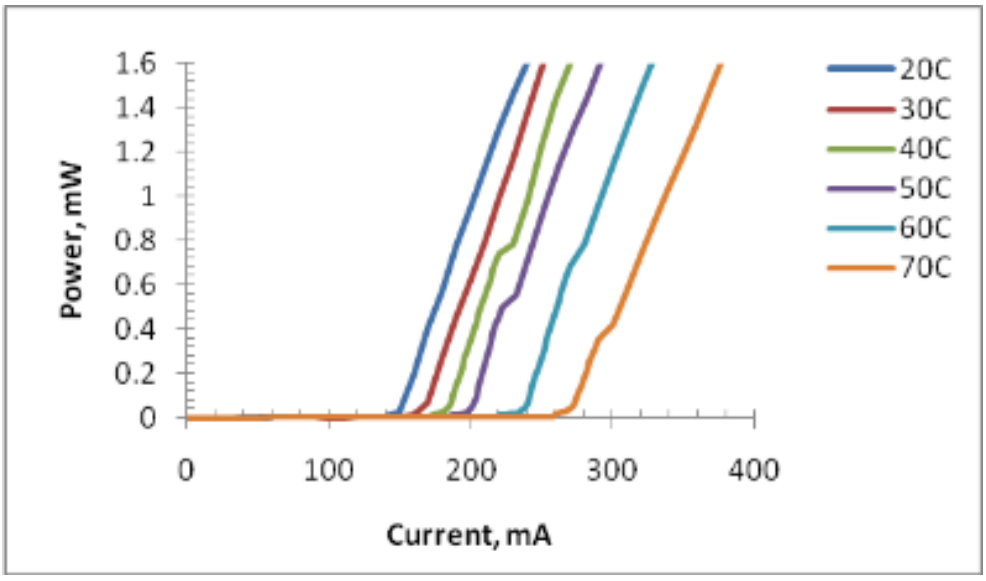


***Figure 2**. L-I curve of chirped MQW device from 20 ℃ - 70 ℃.*

Table 1. *This table illustrates the changes in differential quantum efficiency with a change in temperature.*

Temperature [°C]	Differential Quantum Efficiency (W/A)
20	17.0%
30	14.9%
40	22.3%
50	17.0%
60	15.8%
70	13.7%

Gain Measurements

The experimental setup for this portion of the measurements can be seen in Figure 3.

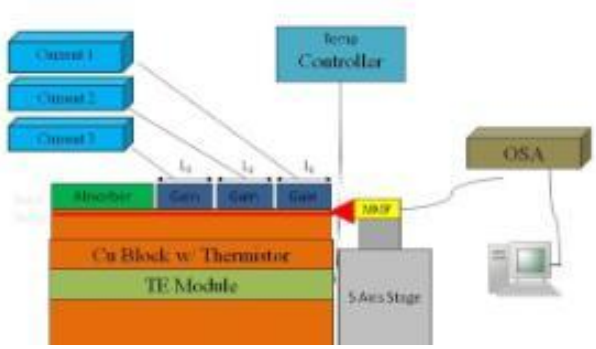


Figure 3. *Schematic of the improved segmented contact method set up used to measure the gain. A multimode fiber (MMF) is used to collect light from the device. Absorption measurements can also be performed on the same set up by applying a reverse bias voltage to section L_2. Data acquisition is performed by LabView and IGOR Pro software packages.*

Using the improved segmented contact method developed in our research group, we are able to measure both gain and absorption of the material. The gain measurements are currently underway for a chirped MQW device emitting at 985 nm. This device was manufactured by Zia Laser originally for a superluminescent LED application.

Future Work

In the near term, a coupled MQW device as well as a reverse chirped MQW device will be studied. Using this information, a better understanding will be achieved on how to tailor the material in such a way that the gain, and consequently the threshold current, maintains a flat profile over a wide range of operating currents. Future work involves using the gain and absorption measurements of this device, as well as other chirped MQW samples and published data, to determine a predictive model in order to calculate the gain of an arbitrary laser material.

VII. UNM Student - Furqan Chiragh

Furqan Chiragh was a PhD student in the Electrical and Computer Engineering Department with a concentration in Optoelectronic. His advisor was Luke Lester. Mr. Chiragh participated in the UNM grant for about one year. During that year he took classes, completed one of his comprehensive exams, apprenticed at AFRL's fiber laser laboratory, and conducted a literature search for a dissertation topic. He had selected photonic band gap fibers for 589 nm light generation as his topic. However, he discovered that this subject did not provide him with a novel enough idea for the pursuit of a PhD.

In consultation with his advisors at UNM and AFRL, Mr. Chiragh decided to withdraw from the grant program to pursue full-time employment. He still hopes to find a suitable topic in crystal fiber amplifiers and continue his studies at a later date.

VIII. UNM Student – Natasa Vretenar

Ms. Vretenar is a PhD student at UNM that has completed all of her candidacy requirements. She is the most recent student on this grant and has chosen for her topic *"Thin Disk Laser: Thermal and Optical Characterization and Optimization."* She expects to graduate in the spring of 2011. Her advisor is Dr. Ganesh Balakrishnan at UNM and her mentor at AFRL is Dr. Tim Newell.

Research Accomplishments To-Date

Characteristics of high power Yb:YAG thin disk lasers (TDL) have been examined both experimentally and theoretically. TDLs were modeled in detail using finite element analysis (thermal and stress) and geometrical/physical optics (to obtain better beam quality). Experimental data gathered included thermal measurements of TD and output couplers, small signal gain, wavefront, spectrum, and fluorescence measurements. The final objective of this research is an efficient, small volume, lightweight laser with high power and high quality beam characteristics.

The main goal of my research is to improve the existing solid-state laser technology and deliver efficient, compact, robust high power with high beam quality laser that can be mounted on an aircraft. AFRL Thin Disk laser research benefits the entire solid-state high power laser community through innovation in materials science (progress in manufacturing ceramic gain media), new thermal management techniques (utilizing novel heat sink configurations and spray cooling), and by obtaining excellent beam quality for high power lasers. The following tasks have already been completed to achieve these goals:

- Tested SiC heat sink disk on a 2cm test bed (Figure 1). Confirmed improved beam quality with a new heat sink configuration. Removed the heat signature of jet cooling. Experimental data indicates that epoxy layer acts as an insulator, so a different epoxy and CADB method to bond heat sinks may be needed;

- Computed the heat distribution in a laser disk using COMSOL modeling (Figure 2). Modeling done for various existing TD configurations (capped, uncapped, with various heat sinks and epoxy layer). Models can be used to further characterize novel composite material configurations;

- Showed that quality of output coupling mirror changes the power output of the laser. Monitored OC's temperature during ramp;

- Calculated cavity stability and Gaussian beam propagation;

- Calculated rate equations for multipass TD system, signal gain, extractable output power and efficiency (Figure 3);

- Calculated absorption and emission cross sections using absorption data and McCumber relations;

- Used ZEMAX to model pump beam free space delivery optical system.

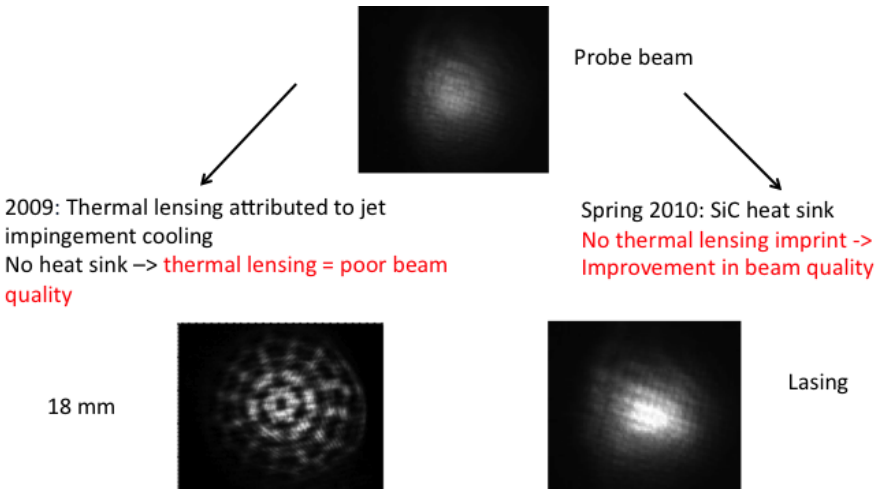


Figure 1. *Thermal lensing experimental data*

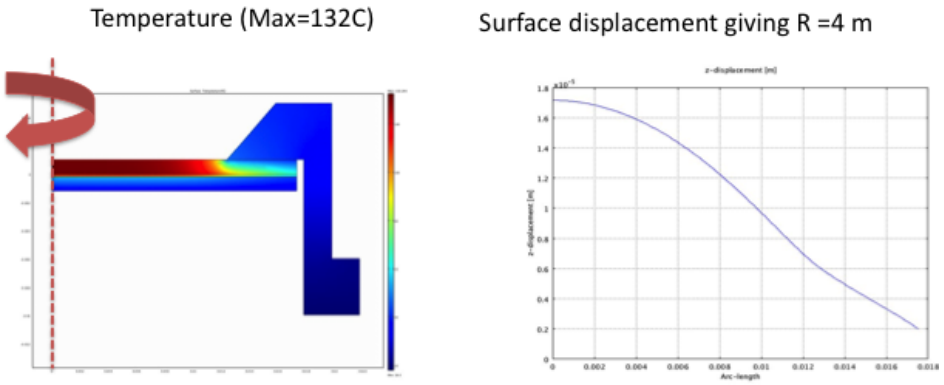


Figure 2. *COMSOL modeling of thermal displacement fo SiC heat sink. Left: two-dimensional cross-section of the deformation (axial symmetry), right: displacement of the top surface of the disk.*

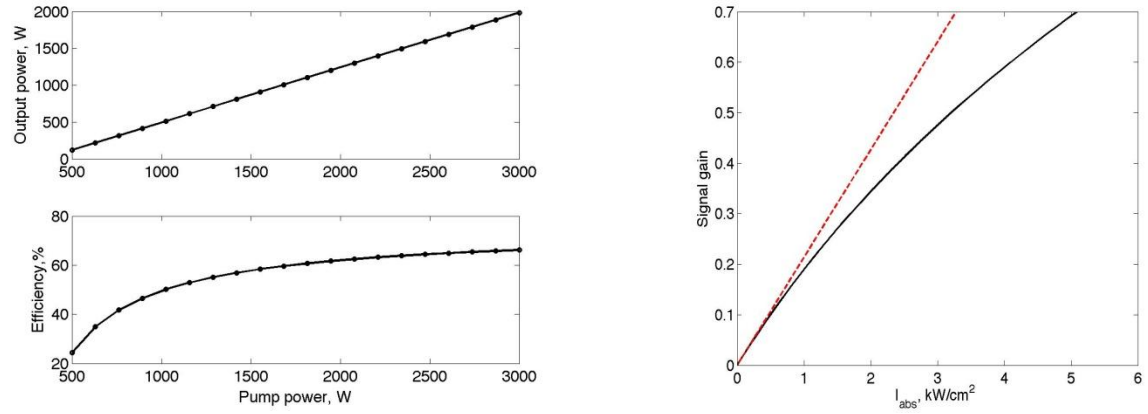


Figure 1. Left: *Output power and efficiency of Yb:Yag disk laser for typical values of parameters. ASE included, but thermal lensing is neglected.* Right: *signal gain for the corresponding disk.*

Future Research Goals

So far, this work has treated thermal deformations due to heat (thermal lensing) and laser quality as independent phenomena. In reality, thermal lensing severely affects the quality of laser beam as well as the undesirable Amplified Spontaneous Emission (ASE), as shown on Figure 4.

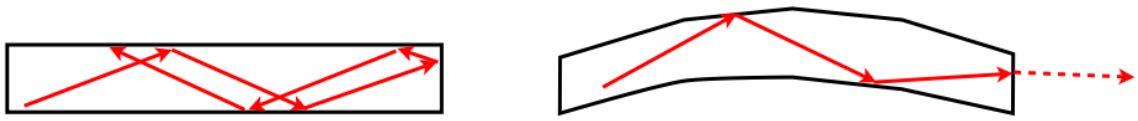


Figure 4. *Change in ASE following thermal deformation.* Left: *undeformed disk;* Right: *disk undergoing thermal deformation.*

Exact calculation of ASE effects is currently impossible, so a reasonable estimate must be made using a combined theoretical and experimental analysis. Since the thermal deformations are small (tens of microns for a 250 micron thin disk), it is natural to assume that ASE changes linearly with the deformation itself. The idea is to measure the thermal lensing effect (using a wavefront sensor) and the temperature of the disk (using a thermal infrared camera) for several values of the pump power. It is then possible to change the heat generation inside the disk in COMSOL program to fit the experimental values. The change in the flux will primarily come from the change in ASE. Such measurements and modeling has never been done before and will be important part of the AFRL laser project design.

In order to minimize thermal lensing, the Yb doping with the distance from the disk center will be attempted. This will affect the generation of the fundamental mode (as well as other modes) in the laser and thus vary the local luminosity and heat generation. The effect of the

doping on the heat generation and deformations will also be studied which will start the process of optimization with regards to doping, although this is a task that is too hard for the current state of doping technology. A detailed plan of the completion of this research follows.

Summer 2010

- Make cooling mount for the output coupler.
- Characterize disks prior to mounting and after mounting (microscope ordered). Characterize disk after testing.
- Get new output couplers with several different radii of curvature.
- Test disks available – capped and uncapped TD with diamond and sapphire heat sinks on a 2 cm testbed. Take thermal data (TD and output coupler). Use wavefront sensor to analyze the laser output beam quality and thermal lensing. Use spectrum analyzer to figure out how many transverse modes present. Done by end of July.
- Start setting up RINI spray cooling system at room temperature as soon as the equipment comes in (July/August). Test disks coming from Precision Photonics (thermal, wavefront, fluorescence, small signal gain and spectrum measurements).

Fall 2010

- Setup RINI for cryogenic operation. Test disks – goal to be done by end of the year 2010.
- Use COMSOL and experimental data to model doping profiles with MATLAB. Study the effect on deformation and thermal lensing.
- Take measurments of wavefront profiles several values of pump powers.
- Upconversion measurements for green light fluorescence. This measurement would allow us to calculate the temperature of the TD (for the capped disks), based on the experimental data from a thermal camera (measures the cap temperature).
- Run COMSOL simulations and predict the ASE change with pump power. Complete the paper on thermal lasing and submit (Nov/Dec 2010).

Spring 2011

- Model the entire TDL system with COMSOL/MATLAB/ZEMAX integrated code. Extend modeling to new composite materials.
- Use different cavity configurations to improve beam quality.
- Finish analysis of doping on laser quality. Complete the paper and submit.
- Continue theoretical work (doping to eliminate higher order modes, etc.)
- Test new materials (Lutetia). Characterize using the same methods used for the existing TDLs.
- Continue testing on RINI setup. Repeat experiments as needed. Analyze data and write up dissertation.

APPENDIX A – Education Partnership Agreement

EDUCATION PARTNERSHIP AGREEMENT

ENTERED INTO BY

THE DEPARTMENT OF THE AIR FORCE
AS REPRESENTED BY
THE AIR FORCE RESEARCH LABORATORY DIRECTED ENERGY DIRECTORATE
AND
THE AIR FORCE INSTITUTE OF TECHNOLOGY

AND

THE UNIVERSITY OF NEW MEXICO

AND

THE NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

I. Preamble

The United States of America as represented by the Department of the Air Force, Air Force Research Laboratory Directed Energy Directorate (hereinafter referred to as AFRL/DE), at Kirtland Air Force Base (hereinafter referred to as KAFB), New Mexico and the Air Force Institute of Technology (hereinafter referred to as AFIT), at Wright-Patterson Air Force Base (hereinafter referred to as WPAFB), Ohio; and the University of New Mexico (hereinafter referred to as UNM), Albuquerque, New Mexico; and the New Mexico Institute Of Mining and Technology (hereinafter referred to as NMT), Socorro, New Mexico hereby enter into this Education Partnership Agreement (hereinafter referred to as the Agreement) pursuant to 10 U.S.C. §2194. In this Agreement, "Educational Institution" has the same meaning as "local educational agency" as given in 10 U.S.C. §2194(e) (2). The terms and conditions of this Agreement are set forth as follows.

II. Introduction

The Parties enter into this Agreement in recognition of the importance of education to the future economic well being of the nation and the importance of the directed energy research efforts of AFRL/DE to the business, industrial, and educational institutions in the United States.

AFRL/DE is the Department of Defense's center of expertise for lasers, high-power microwaves, and other directed energy technologies. As a defense laboratory, AFRL/DE encourages the study of science, mathematics, and engineering at all levels of education by entering into Education Partnership Agreements with educational institutions in the United States, giving priority to educational institutions serving women, members of minority groups, and other groups of individuals who traditionally are involved in the engineering and science professions in disproportionately low numbers.

UNM is classified as a minority institution because the majority of its students are composed of minority Hispanics. UNM is designated as a Doctoral/Research University, and offers a wide-range of

undergraduate and graduate programs, including graduate programs in physics, chemical and nuclear engineering, and other disciplines.

NMT offers undergraduate and graduate programs emphasizing math, science and engineering, including graduate programs in physics, optics, electrical engineering, and other disciplines.

AFIT offers graduate programs leading to Master of Science and Doctor of Philosophy degrees in engineering, applied science, and management disciplines. The school is focused on preparing students with the skills required to maintain the world's best Air Force, with the recognition of research as a critical element in quality graduate education.

III. Objective

Making use of the authority cited in Article IV, the Parties seek to be recognized as a center of excellence for high power lasers through their efforts to advance opportunities for education and research in the disciplines of laser physics, optics, electrical engineering, plasma-physics, and physical chemistry and to aid in the development of the next generation of user friendly high power lasers by making full use of their respective education programs, academic and practical expertise, and equipment and facilities, such as the AFRL/DE Gas Laser Facility (GLF).

IV. Authority

As provided by Department of Defense Directive 5535.3 (21 May 1999), this Agreement is entered into pursuant to the Education Partnership Act, 10 U.S.C. §2194, for the purpose of encouraging and enhancing science, mathematics, and engineering education. Under 10 U.S.C. §2194, AFRL/DE may provide assistance by:

> (1) loaning defense laboratory equipment to the institution for any purpose and duration in support of such agreement that the director considers appropriate;
> (2) notwithstanding the provisions of Subtitle I of Title 40 [40 USCS §§ 101 et seq.] and Title III of the Federal Property and Administrative Services Act of 1949 (41 U.S.C. 251 et seq.) or any provision of law or regulation relating to transfers of surplus property, transferring to the institution any computer equipment, or other scientific equipment, that is--
> (a) commonly used by educational institutions;
> (b) surplus to the needs of the defense laboratory; and
> (c) determined by the director to be appropriate for support of such agreement;
> (3) making laboratory personnel available to teach science courses or to assist in the development of science courses and materials for the institution;
> (4) involving faculty and students of the institution in defense laboratory research projects;
> (5) cooperating with the institution in developing a program under which students may be given academic credit for work on defense laboratory research projects; and
> (6) providing academic and career advice and assistance to students of the institution.

V. Obligations

a. Each of the Parties shall designate a representative to serve on an Oversight Board. It will be the responsibility of the board collectively to identify projects that are consistent with the objectives

and authorities set out in Articles III and IV above, and to develop and implement plans to carry out those projects.

b. Generally, AFRL/DE is responsible for the day-to-day functional operation and safety of the GLF and other AFRL/DE facilities made available under this agreement. When experiments are conducted at AFIT or UNM or NMT, those organizations shall be responsible for the functional operation and safety of their facilities.

c. More specific obligations of the Parties are described in Appendix A, entitled Obligations of the Parties.

d. Unless otherwise specifically agreed upon in writing, none of the Parties shall be obligated to compensate another Party for costs incurred in carrying out activities defined by this Agreement. The home organization of each participant shall be solely responsible for tuition fees, travel or other costs incurred by their respective students and personnel. The parties shall independently seek funding through channels available to them to support the projects and objective of this agreement. The Parties' obligations under this Agreement are contingent upon and subject to availability of funds.

e. Students who undertake research projects under this agreement require a commitment of financial support and academic mentorship to enable the students to complete their degrees. Accordingly, decisions as to funding, curriculum and staff will be mindful of the risk of disrupting the education programs of students.

f. Any public announcement of this Agreement shall be coordinated among the Parties to include the AFRL/DE public affairs office. The Educational Institutions shall not use the name of AFRL/DE or the federal government on any product or service that is directly or indirectly related to this Agreement without prior written approval of AFRL/DE. Similarly, AFRL/DE shall not use the name of the Educational Institutions on any product or service that is directly or indirectly related to this Agreement without prior written approval of the affected Educational Institution. By entering into this Agreement, none of the Parties, directly or indirectly endorses any product or service provided, or to be provided, by the other Parties. None of the Parties shall in any way imply that this Agreement is an endorsement of any such product or service.

g. The mission of academic institutions such as UNM and NMT is to produce fundamental research. However, if classified or restricted research is conducted under this agreement, it must be undertaken in with appropriate safeguards, which should be consistent with the principles of academic freedom required to ensure opportunity for academic success of participating students. Generally, research projects conducted under this Agreement will not require access to classified materials, and participating faculty and students will not be required to obtain security clearances. Nevertheless, work on certain projects may require the Educational Institutions' faculty and students have access to proprietary information in the possession of AFRL/DE or information for which export is restricted by the Arms Control Act, 22 U.S.C. §2571 et seq., or the Export Administration Act, 50 U.S.C. §2401 et seq., or the International Traffic in Arms Regulation, 22 C.F.R. §120-25, as military-critical technology, or that is otherwise protected from disclosure by statute, executive order, or regulation. In such cases, to obtain access to this information, faculty members and students must comply with the requirements for disclosure contained in the statutes, executive orders, or regulations, including signing nondisclosure agreements, before a disclosure of such information may be made by

AFRL/DE. This may mean that only United States citizens are eligible to be participating faculty or students under this Agreement.

h. As an additional precaution designed to insure compliance with the statutes and regulations identified above, any publications resulting from this Agreement, such as conference papers, invited presentations, and/or scientific journal articles, are subject to review by the AFRL/DE public affairs office prior to submission for publication. The AFRL/DE Program Manager for this Agreement will facilitate and provide public affairs office contact information.

i. The Parties will negotiate the loan or donation of any equipment to be provided under this Agreement and document the terms of that loan or donation in an addendum to this Agreement.

VI. Administration

a. The Program Manager for each Party shall ensure that program activities meet applicable statutory and regulatory requirements of the federal government, the Department of the Air Force, the State of New Mexico, the Department of Education and the Educational Institution.

b. The Director of AFRL/DE will initially serve as the program manager for AFRL/DE, but may delegate the function of program manager as he deems appropriate. He will work with the program managers for the Educational Institutions to identify, select, and prioritize the activities in which the Parties engage pursuant to this Agreement, and will ensure that program activities meet the statutory and regulatory requirements of the federal government and the Department of the Air Force. The contact information for the foregoing is set out below:

Director
Air Force Research Laboratory, Directed Energy Directorate
3550 Aberdeen Avenue SE
KAFB, New Mexico 87118-5776
Phone (505) 846-0860
Fax (505) 853-1753

c. Dr Marlin U. Thomas, Dean, Graduate School of Engineering and Management, AFIT; Dr John K. McIver, Senior Associate Vice President for Research and Economic Development, UNM; and Dr Van Romero, Vice President for Research, NMT will serve as the partnership program managers on behalf of their respective institutions, but may delegate program manager responsibilities as the deem appropriate. They will work with the program manager for AFRL/DE to identify, select, and prioritize activities in which the Parties engage pursuant to this agreement, and will ensure that program activities meet the federal, state and local statutory and regulatory requirements applicable to their institutions. The contact information for the foregoing is set out below:

Dr Marlin U. Thomas, Dean, Graduate School of Engineering and Management
Air Force Institute of Technology
Wright-Patterson AFB, Ohio 45433-7765
Phone (937) 255-3636, extension: 7101
Fax (937) 656-6000
E-Mail marlin.thomas@afit.edu

Dr John K. McIver
Senior Associate Vice President for Research and Economic Development
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Albuquerque New Mexico 87131
Phone (505) 277-6128
Fax (505) 277-5271
E-Mail jmciver@unm.edu

Dr Van Romero, Vice President for Research
New Mexico Institute of Mining and Technology
Socorro, New Mexico 87801
Phone (505) 835-5646
Fax (505) 835-5649
E-Mail VRomero@nmt.edu

VII. Deliverables

The UNM shall deliver a simple letter report (less than two pages) at the end of each fiscal year of this agreement. The report will document student and faculty participation under this agreement.

VIII. Value of Contributions

If requested by any Party, a non-requesting Party will provide a cost estimate of the value of its contribution to this Agreement. Such estimate will include equipment, facilities and manpower. Current estimated contributions are:

a. The estimated value of contributions from the Educational Institutions to this Agreement is $500,000. The approximate breakdown is as follows:

1) Labor (teachers, staff, students, and support personnel)	$350,000
2) Supplies, equipment and miscellaneous	$150,000
3) TOTAL	$500,000

b. AFRL/DE estimates the value of its contributions to this agreement to be $500,000. The approximate breakdown is as follows:

1) Labor (scientists, engineers, and support personnel)	$300,000
2) Facilities	$50,000
3) Supplies, equipment and miscellaneous	$150,000
4) TOTAL	$500,000

IX. Benefits

a. Benefits to the Educational Institutions, their students and the State of New Mexico include:

1) A formal vehicle for information exchange with AFRL/DE, the Air Force focal point for directed energy technology.

2) Access to state of the art directed energy technologies for research. Insight into Air Force and Department of Defense future directed energy technologies.

3) A forum for participants to exchange ideas and information that may lead to teaming arrangements or other formal agreements for pursuing competitive research projects and grants.

4) Opportunities for further collaboration between the Educational Institutions and AFRL/DE on various technology transfer projects that will strengthen overall United States competitiveness as well as improve economic development through the application of AFRL/DE technologies.

5) Improved educational relevance to academic programs as a result of closer interaction with AFRL/DE personnel and research projects based upon practical, "real world" problems and needs.

b. Benefits to AFRL/DE and the Air Force include:

1) Promoting the education of future scientists and engineers.

2) Good will.

3) Enhancing AFRL/DE scientists, engineers and managers as a result of conducting research in conjunction with academic and practicing professionals who work in Directed Energy Science & Technology.

4) Perform research important to Air Force in conjunction with academic and practicing professionals who are knowledgeable in the directed energy field.

X. Liabilities

To the extent permitted by the respective federal or state laws governing the Parties, each Party shall be responsible for claims brought against it for personal injury or property damage, or for any other type of injury or damage, to the extent such injuries or damage result from the negligence of its employees, agents, instructors or students.

XI. Patents and Copyrights

Each Party shall separately own any invention made solely by its respective employee(s). The Educational Institutions shall grant the federal government a world-wide, royalty-free, nonexclusive license to make, sell or use, and to have or permit others to do the same, for federal government purposes only, all inventions made under this agreement and owned by an Educational Institution. Inventions made jointly by the Parties shall be jointly owned by the inventing Parties. Joint licensing of intellectual property, if any, shall be set out in separate agreements. In the event copyrightable works are created under this Agreement, the Educational Institution shall own the copyright in all works created in whole or in part by employees of that Educational Institution, and grants in advance a world-wide, royalty-free, nonexclusive license in favor of the federal government conveying the right to use, duplicate or disclose such works in any manner, and to have or permit others to do the same, for federal government purposes only.

XII. No Benefits

No member of, or delegate to the United States Congress, or resident commissioner, shall share in any part of this Agreement, nor in any benefit that may arise from this Agreement.

XIII. *Force Majeure*

None of the Parties shall be liable for any unforeseeable event beyond its reasonable control not caused by the fault or negligence of such Party, which causes such Party to be unable to perform its obligations under this Agreement, and which it has been unable to overcome by the exercise of due diligence, including, but not limited to, flood, drought, earthquake, storm, fire, pestilence, lightning and other natural catastrophes, epidemic, war, riot, civil disturbance or disobedience, strikes, labor disputes, or failure, threat of failure, or sabotage, or any order or injunction issued by a court or public agency. In the event of the occurrence of such a *force majeure* event, the Party unable to perform shall promptly notify the other Party. It shall further use its best efforts to resume performance as quickly as possible and shall suspend performance only for such period of time as is necessary as a result of the *force majeure* event.

XIV. Risk of Loss

The Educational Institution shall return any and all federal government-owned equipment loaned under this Agreement to AFRL/DE in good working order, normal wear and tear excepted, at the end of the time period(s) for loan or (30) days prior to the end of this Agreement, which ever comes first. While in the care or possession of the Educational Institution, the equipment shall be covered by the Educational Institution's insurance program. Any repairs or modification to the government-owned equipment that the Educational Institution may find necessary to make shall be performed only after receiving written approval of AFRL/DE. Any such repair or modification shall be at the expense of the Educational Institution and shall not affect the title of AFRL/DE to said equipment.

XV. Period of Agreement

a. The Agreement shall commence on the date of the last signature affixed below. Any Party may terminate its involvement in this Agreement by delivery of a written notice at least 30 days in advance of the prospective termination date. Termination of this Agreement by any Party for any reason shall not affect the rights and obligation of the Parties accrued prior to the effective date of termination of this Agreement. If any Party requests modification of this Agreement, including an extension of this Agreement, the Parties shall, upon reasonable notice of the proposed modification by the Party desiring the change, confer in good faith to determine the feasibility of such modification. Modifications shall not be effective until a written amendment is signed by duly authorized representatives of all Parties. If any Party terminates this Agreement, it shall not be liable for any costs resulting from or related to the termination, including but not limited to, consequential damages or any other costs experienced by another Party or third parties, deriving rights their through a Party, including the faculty, students or employees of the Parties.

b. The specific term of this agreement is 5 years from the date of the last signature affixed below.

IN WITNESS WHEREOF, the Parties have caused this Agreement to be executed in duplicate.

AIR FORCE RESEARCH LABORATORY/ DIRECTED ENERGY DIRECTORATE:

Sign: _____

Name: KIRK M. KLOEPPEL, Col., USAF

Title: Acting Director, Directed Energy Directorate

Date: _____

AIR FORCE INSTITUTE OF TECHNOLOGY

Sign: _____

Name: DR MARLIN U. THOMAS

Title: Dean, Graduate School of Engineering and Management

Date: _____

UNIVERSITY OF NEW MEXICO

Sign: _____

Name: TERRY L. YATES

Title: Vice President for Research and Economic Development

Date: _____

NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY:

Sign: _____

Name: LONNIE MARQUEZ

Title: Vice President for Administration & Finance

Date: 11/7/06

APPENDIX A
OBLIGATIONS OF THE PARTIES

I. Specific Obligations

a. AFRL/DE shall:

1. Provide technical expertise, research oversight and direction concerning future applications of directed energy; and assist in teaching and developing pertinent courses of study and research efforts in this area.

2. Identify means and methods of involving faculty and students in AFRL/DE research projects in ways that may allow students academic credit for working on these projects.

3. Involve its scientist and engineers in providing academic and career advice to Educational Institution students.

4. Make available to the other Parties the GLF on KAFB and other AFRL/DE facilities and equipment, under terms and conditions that satisfy AF safety and security requirements, for purposes consistent with carrying out this Agreement; and be responsible for the day-to-day operations and maintenance of the GLF.

5. Any equipment loaned or transferred to an educational institution in support of this agreement shall be documented in Annex 1 – Equipment on Loan to Educational Institution or Annex 2 – Equipment for Donation to the Educational Institution, as appropriate.

6. Allow the GLF to be used for office space, laboratory space and administrative support for experimental research efforts conducted under this agreement.

7. Be responsible for coordinating access to KAFB, its computer network and other infrastructure support, as necessary, and ensuring compliance with base safety, environmental and training procedures and regulations.

b. UNM, NMT and AFIT will:

1. At their discretion, through appropriate mechanisms, arrange to include students and professors from other universities in the activities carried out under this agreement. Arrangements for reciprocal credit and joint academic appointments will be the subject of separate agreements among the academic institutions.

2. Provide academic instruction, guidance, and research expertise.

3. Seek funding through grants and other instruments for fundamental research (6.1 funded fundamental researches) and other projects relevant to the objectives of this Agreement from a variety of sources, including the National Science Foundation.

4. Ensure that students are eligible for academic credit toward requirements of an appropriated degree program for research performed under this Agreement.

5. Be responsible for all the Educational Institution's faculty, student, and other employee salaries or other compensation and benefits for activities or work performed under this Agreement and be responsible for tuition, fees, and travel incurred by their respective students and personnel.

6. Supervise students and post-doctoral fellows and ensure that the Educational Institution's students, faculty and staff comply with all KAFB access procedures and with AFRL/DE safety and security procedures.

7. Ensure that post-doctoral level research conducted at the Center will be eligible for publication within the professional peer reviewed literature.

8. Be responsible for round-trip transportation of AFRL/DE donated or loaned equipment and be responsible for all costs for setup, checkout, repair, re-fabrication, and maintenance of AFRL/DE donated or loaned equipment.

DEPARTMENT OF THE AIR FORCE
AIR FORCE RESEARCH LABORATORY (AFMC)

9 November 2006

Air Force Research Laboratory (AFRL)
Tech Transfer Support Group
3550 Aberdeen Avenue, Building 497
Kirtland AFB, NM 87117-5776

Dr. John K. McIver
Senior Associate Vice President for Research and Economic Development
University of New Mexico
Albuquerque, NM 87131
Phone (505) 277-6128

Dear Dr. McIver,

Enclosed are 5 original copies of an Education Partnership Agreement (EPA) between the Air Force Research Laboratory, Directed Energy Directorate and The Air Force Institute of Technology, The University of New Mexico, and New Mexico Institute of Mining and Technology.

Please sign and date the documents and return all three to the following address:

Melissa R. Ortiz
Tech Transfer Support Group
3550 Aberdeen Avenue
Bldg 497, Rm 232
Kirtland AFB, NM 8711-5776
Phone (505) 846-6377

As soon as we receive the fully signed originals Ms. Ortiz will forward one for your records. If you have any questions, please do not hesitate to call or email Ms. Ortiz at melissa.ortiz@kirtland.af.mil

PONZIANO FERRARACCIO
ORTA

Enclosures:

The University of New Mexico

Office of Research Services
Scholes Hall 102
MSC05 3370
1 University of New Mexico
Albuquerque, NM 87131-0001
http://research.unm.edu

December 18, 2006

To: Gerald Mora, Air Force Research Laboratory/DE
From: Roland Wildman, Sponsored Project Services
Subject: Education Partnership Agreement between AFRL/DE and AFIT, UNM and NMT

Enclosed please find five (5) copies of the agreement referenced above with original signatures. Please return one copy to my attention upon full execution of the agreement.

Thanks for your help with this.

Sincerely,

Roland Wildman
Operations Manager
Sponsored Project Services

Enclosures

APPENDIX B - Enhanced Equipment Purchases

Table 1. List of equipment

Equipment Item Description	Purpose
FROG Scan SHG FROG ultrafast laser pulse measurement system for 1240 nm. 300 micron thick BBO crystal. Input range 1100 nm - 1420 nm with fiber coupling.	The FROGSCAN unit is a unique tool that measures the dispersion and chirp characteristics of ultrafast (< 20 ps) light pulses. This equipment is critical for understanding how to compress the mode- locked laser pulses and thereby increase the peak power of the device.
Powerlite Precision II Series Nd:YAG Laser, Model 8000: Oscillator / Amplifier, 10 Hz; with Second Harmonic Generator (for spec energy at 532 nm); and wavelength separation optics for second harmonic output.	The Powerlite Nd:YAG laser will be used to pump an optical parametric oscillator (OPO). This OPO requires a narrow-band pump source, which the seeded Powerlite laser provides. The laser system will allow us to test several molecules for their usefulness in optically pumped molecular lasers. In particular we will test acetylene and HCN. Both have absorption bands in the 1.5 micron region that coincides with the C-band of telecommunication fiber lasers. With the ns OPO we can measure molecular rate constants that are important for assessing the lasing potentials of those molecules. The Nd:YAG pumped OPO will also allow us to demonstrate lasing from those gases with a pulsed pump source.
ANDO 6317B, used rental equipment	This OSA would be dedicated to optical characterization of the gain and loss parameters of the quantum dot materials. Its 15 pm resolution and slower data acquisition speed is more suitable for this kind of application where the operating ranges are known and we primarily need good signal-to-noise ratio.
Optical Spectrum Analyzer with adapters	The Yokogawa OSA is necessary for fast, high resolution (10 pm) spectral measurements of the locking bandwidth in the mode-locked laser. This equipment is critical towards making an accurate measurement of whether the spectral haracteristics of the mode-locked laser are Fourier-limited. The fast acquisition speed would enable us to examine the performance for many different device operating conditions in a reasonable time.
Tektronix DSA8200 oscilloscope with heads	The DSA8200 is important for RAPID characterization of the pulse duration from different mode-locked laser cavity geometries. This unit would make measuring pulses fast and easy and would enable us to identify optimal laser operation where very detailed pulse characterization could be done with the FROGSCAN. (Cost does not include low bankwidth optical head shown in quote.)

In order to improve the ability of the university to conduct high quality laser research in areas of interest to the Air Force, several important pieces of equipment were acquired through this grant. Table 1 above shows these items and the purpose that they serve. Some additional information on the importance of this equipment for the students is also provided.

Powerlite Precision II Series Nd:YAG Laser

The acquisition of a Q-switched Nd:YAG laser with funds provided by the COE allowed us to set up a nanosecond optical parametric oscillator and amplifier (OPA). This pulse source was instrumental to demonstrate for the first time molecular acetylene and HCN lasers emitting at 3 microns when pumped at wavelengths from the telecomm C band. Using the OPA we also built the first gas filled hollow core fiber laser based on population inversion. Two graduate students

and one postdoctoral research associate were involved in these projects. They gained valuable experience in gas spectroscopy and optically pumped lasers. In addition this instrument was used by a graduate student from Kansas State University through collaboration with the group of Prof. Corwin. So far two journal papers have been submitted and two conference talks were presented at Photonics West and CLEO.

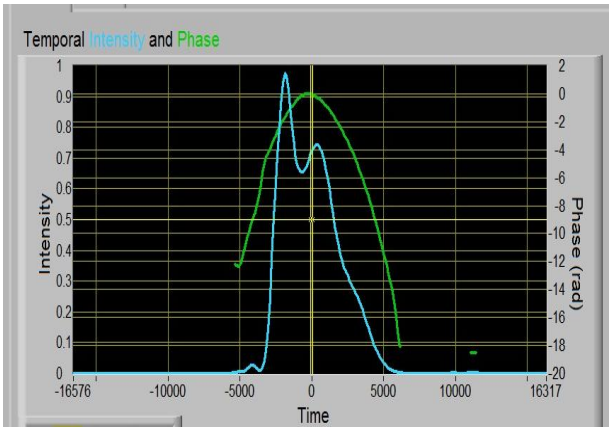
Tektronix DSA8200 oscilloscope

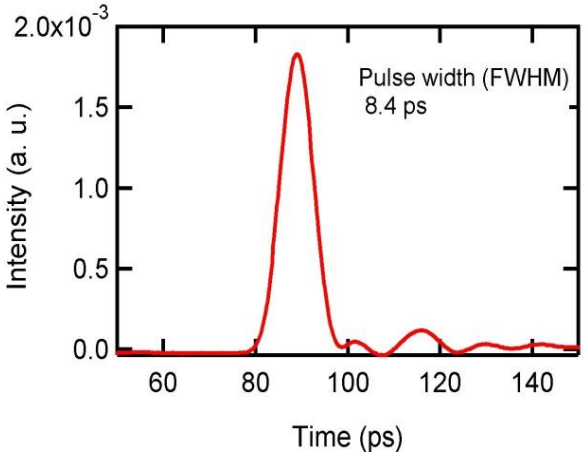
The Tektronix DSA8200 digital sampling oscilloscope with a high-speed optical head has been invaluable for characterization of the pulse duration from different mode-locked laser cavity geometries. This equipment make measurement of pulses fast and easy and enable students to identify optimal laser operation where very detailed pulse characterization is done with the FROGSCAN unit that was purchased from Mesa Photonics.

FROG Scan SHG FROG ultrafast laser pulse measurement system

The FROG Scan unit is a unique tool with very high sensitivity that measures the dispersion and chirp characteristics of ultrafast (< 20 ps) light pulses. This equipment is critical for understanding how to compress mode- locked laser pulses and thereby increase the peak power of the device.

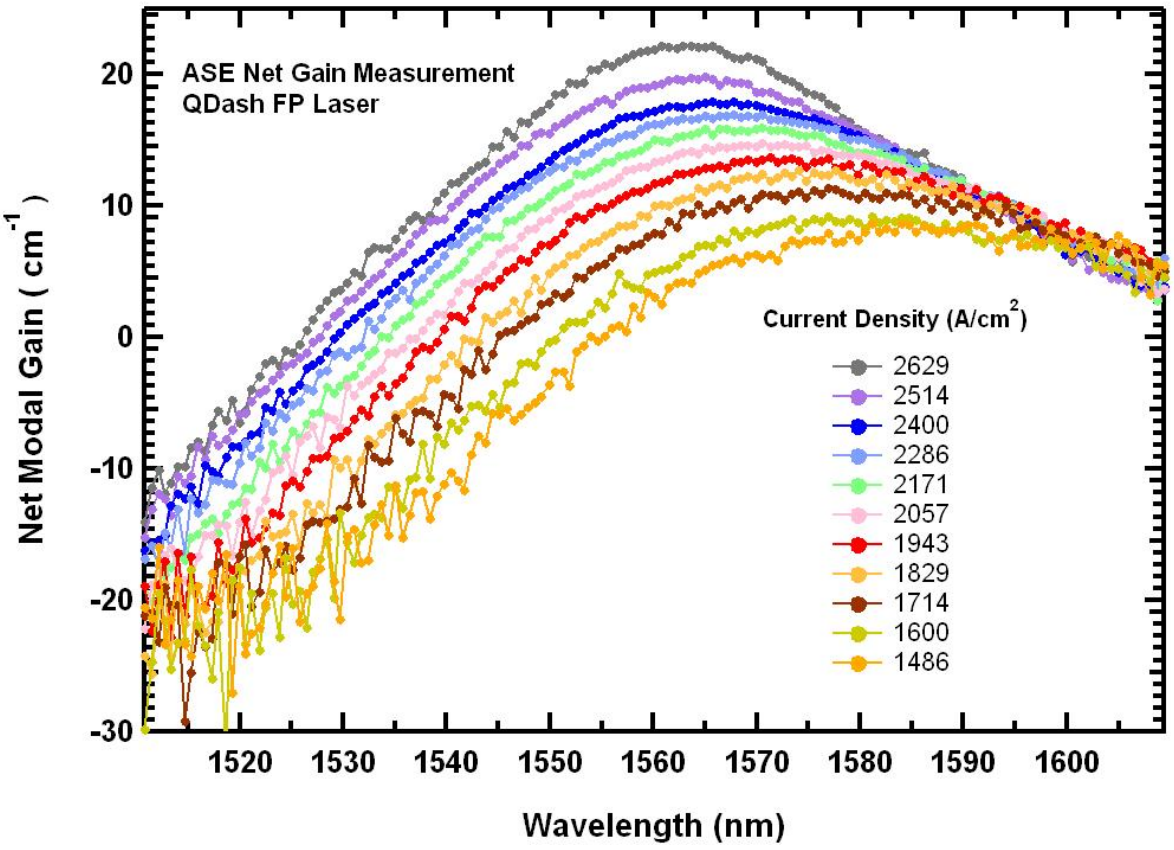
Below is a comparison of the same pulse from a 1240 nm quantum dot mode-locked laser measured by the Mesa Photonics FROG Scan (on the left) and the Tektronix DSA8200 (on the right). The FROG Scan device measures the actual pulse duration of 4.2 ps and its associated shape. The precise definition of the mode-locked laser pulse by the FROG Scan allowed us to calibrate the speed of the Tektronix sampling scope. Although rated at an 80 GHz performance specification, our DSA8200 has an actual bandwidth of 140 GHz. Assuming Gaussian-shaped pulses, the figure-of-merit for the bandwidth was deduced from the measured 8.4 ps pulse width in the Tektronix versus the actual pulse width.





Yokogawa and Andro Optical Spectrum Analyzers

The Yokogawa and Ando Optical Spectrum Analyzers that were purchased on the COE grant are well-suited for fast, high resolution (10 pm) spectral measurements of the available gain bandwidth in semiconductor optical materials. This equipment was critical towards making an accurate measurement of whether the spectral characteristics of a quantum dot mode-locked laser are Fourier-limited. The fast acquisition speed also allowed us to examine the performance of many different device operating conditions in a reasonable time. Below is a measured optical gain spectrum of an InAs quantum dash laser diode as a function of different pumping levels in the device. The characteristics are measured below threshold.



APPENDIX C – Non-UNM Grant Students

As mentioned in the Introduction, the COE for HEL includes a much broader context than the grant issued to UNM from AFOSR in August 2006. A very strong collaboration among AFRL, UNM, NMT and AFIT was established in the partnership described in detail in Appendix A. While it is beyond the scope of this report to discuss the details of this entire collaboration (those projects not funded by the UNM grant) the table in this appendix shows the depth of the COE with a table of other students who have contributed to its mission.

HEL COE STUDENTS

	LAST NAME	FIRST NAME	UNIVERSITY	ADVISOR	DEGREE SOUGHT	GRADUATION	THESIS TOPIC
1	LANG	MATT	AFIT	Glen Perram	Ph.D.	Sep 2009	Electric Discharge Pumped Oxygen-Iodine Laser
2	PHILLIPS	GRADY	AFIT	Glen Perram	Visiting Faculty	Mar 2009	Saturation Spectroscopy and Velocity Changing Collisions in Rubidium
3	PITTS	GREG	AFIT	Glen Perram	Ph.D.	Dec 2010	Pressure Broadening and Spin-Orbit Kinetics of Cs D1 and D2 Lines
4	JONES	PAUL	AFIT	Glen Perram	M.S.	June 2010	Energy Pooling and Multi-photon dynamics in Rubidium
5	RICE	CHRIS	AFIT	Glen Perram	Ph.D.	Mar 2011	Field Deployable Tunable Diode Laser Absorption Spectroscopy ofr HEL Atmospheric Ch
6	ANDERSON	MONTE	AFIT	Glen Perram	Ph.D.	Sep 2010	Slow Light Inteferometry and Remote Sensing using Cs Hyperfine Splitting
7	BLANK	L. AARON	AFIT	David Weeks	Ph.D.	Dec 2011	Pontential Energy Surfaces for Alkali - Rare Gas Collisions
8	BROWN	KIRK	AFIT	Glen Perram	Ph.D.	Sep 2011	Novel Optically Pumped Gas Phase Laser Resonators
9	THORNTON	DOUGLAS	AFIT	Glen Perram	M.S.	Mar 2010	Saturation Spectroscopy and Velocity Changing Collisions in Rubidium
10	SULHAM	CLIFF	AFIT	Glen Perram	Ph.D.	Sep 2010	Diode Pumped Laser Demonstrations, Scaling and Characterization
11	MILLER	WOODY	AFIT	Jeremy Holtgrave	M.S.	Mar 2010	Diode Pumped Laser Demonstrations, Scaling and Characterization
12	LEWIS	CHARLETON	AFIT	Glen Perram	M.S.	Mar 2009	DPAL Bleached Wave Analysis
13	HACKETT	SHAWN	AFIT	Jeremy Holtgrave	M.S.	Mar 2010	DPAL Device Modeling
14	ROBIN	CRAIG	UNM	Luke Lester	Ph.D.	December 2010	Novel photonic crystal fibers for single frequency fiber amplifiers
15	VERGIEN	CHRIS	UNM	Tom Shay ??	M.S.		Power scaling limits of current single frequency photonic crystal fibers
16	LU	ANDY	UNM	Tom Shay??	M.S.		All-fiber isolators for high power operation
17	PULFORD	BENJAMIN	UNM	Tom Shay??	Ph.D. (OSE)	December 2010	Novel applications of phased array of fibers
18	ZMUDA	MICHAEL	UNM	Jean-Claude Diels	Ph.D.	August 2009	SBS mitiagation in optical fiber amplifiers
19	ZERINGUE	CLINT	UNM	Shay/Lester	Ph.D. (OSE)		

This table shows only the graduate students (Masters, PhD) who have participated in the HEL COE outside of the AFOSR/UNM/NMT grant. Because of the tenacious recruiting efforts of Dr. David (Tony) Hostutler of the High Energy Laser Division at Kirtland AFB, many undergraduate students have been afforded the opportunity to study and work alongside of AFRL scientists, post-docs (one hired through the UNM grant), and graduate students at the AFRL COE facilities. Some of these students spent the entire summer working on projects designed by Dr. Hostutler while others were involved during the school semester working on Senior Design Projects. As an example of the undergraduate participation in the COE, the following pages show one UNM senior design team requirement specification put together by the team (three) of students to work on a project at Kirtland AFB in the area of DPALs.

Frequency Locking Diode Control System
ECE 419- Fall 2007
The University of New Mexico

Billy Dytzel
Lucus Ervin
Maria Rosado

Overview

For the last 3 decades, high-power laser development has revolved around two types of laser technology, gas/chemical and solid-state lasers. While both possess their own unique positive attributes, both tend to suffer several negative drawbacks. The primary benefit of the new DPAL (Diode Pumped Alkali Laser) technology is the fact that they appear to adopt the positive characteristics of each while suffering none of the drawbacks. In a sense, the DPALs bridge the gap between the gas and chemical laser and the solid-state technology. As the research in the field of DPALs continues to grow, there is a growing need for a frequency locking system.

The Center of Excellence (COE) (recently established in Directed Energy/Laser Division (DEL) which studies electrically excited gas phase hybrid lasers, in conjunction with Air Force Research Laboratory/High Power Gas Laser Branch (AFRL/DELC) is embarking on a program to study a new class of lasers. These lasers are Diode Pumped Alkali Lasers (DPAL's) which are three level laser systems in which the outer single 2S1/2 electron of an Alkali metal is promoted by optical pumping to the lowest excited 2P3/2 state. Rapid relaxation of the 2P3/2 state to the closely spaced 2P1/2 state then produces a population inversion and lasing between the 2P1/2 -> 2S1/2 states. These laser systems offer the potential to be very efficient (greater than 90%).

The purpose of this project is to implement a control system that is able to frequency lock a series of laser diodes through injection seeding. The deliverables to the client include a diode that can be locked to alkali transition for at least one hour and a control system that is able to handle and adapt to variations in temperature and current to the system. The sample cell alkali element to be used will be potassium. The previous experimental work by other groups utilized rubidium, but the customer (AFRL/DELC) would like to explore new avenues with a different element. Being the there has not been a significant amount of experimentation with potassium in these labs, there is potential for unexpected results and variations.. The supplies and equipment required for this project will be furnished by AFRL. We anticipate the bulk of the research to be done off base. If the need arises that more time will be spent working on base, we shall accommodate it.

Statement of Problem

The goal of this project is to have a diode that can be locked to alkali transition for at least one hour. Temperature and current will cause variations in the diode performance. The temperature should stay locked within .1 to .2 °C. Temperature should be around (20-30°C). The current may go over a 10mA drift but it must be stable. The sample cell to be used will be of potassium.

Previous experiments conducted have used Rubidium, but our customer would like to see new experiments with the alternative element.

The control system is used to steady the frequency of the laser diodes. Variations in temperature, current, and even mechanical vibrations can change the output frequency of the laser light. The control system consists of a laser intensity measurement at a certain frequency, a process or program to determine how to adjust the current to correct fluctuations in frequency, and a current controller to carry out the program. A computer monitor may also be used that will display the current changes in real time, and a fine tuning adjustment control for a user.

The testing process cycle we shall implement for this project is as follows: predict laser performance, compare with experimental results, resolve discrepancies, and refine the model.

Requirements Specification

The following table is a tentative list of needed supplies and equipment. Much of the list must be refined and determined. We were given a lot of freedom in the method of the control system interface, and we are currently researching possible computer applications but are leaning toward Labview due to its availability at school and user friendly interface.

Parameter	Quantity/Method	Available?
Sample Cell	Potassium (K)	On site –yes
Diode Type	TBD based on wavelength	Can be funded
Diode Amount	TBD based on experimentation	Can be funded
Control System Interface	Labview (tentatively)	At UNM – yes
Frequency Locking Method	Injection Seeding	---

Table 1: Requirement Specification

Design Deliverables

The deliverables of the project include a diode that can be frequency locked to alkali transition for at least one hour and a control system that is able to handle and adapt to variations in temperature and current to the system. Temperature and current will cause variations in the diode performance. The temperature should stay locked within .1 to .2 °C. Temperature should be around (20-30°C). The current may go over a 10mA drift but it must be stable.

For the control system deliverable, it must steady the frequency of the laser diodes. The control system consists of a laser intensity measurement at a certain frequency, a process or program to determine how to adjust the current to correct fluctuations in frequency, and a current controller to carry out the program. A computer monitor may also be used that will display the current changes in real time, and a fine tuning adjustment control for a user.

The experiments shall be documented in the group's combined laboratory notebook. If possible there will always be at least 2 people working an experiment each time. Both shall be taking notes and their respective notes will be compared and a comprehensive combination of the notes will be properly documented in the notebook.

Design Deliverables

System testing will be done at various stages of the project development. Each subsystem of the control will be tested individually with sample inputs before it will be installed into the main design. The exact details on how each subsystem will be tested is yet to be determined. For example, the laser intensity measurement system may or may not require measuring the physical laser on base. If it is possible to test the system on campus, we do not yet know. Once each subsystem has been tested and installed, final testing in accordance with our goal (as previously stated) will occur.

I note that you haven't included any references for this work. Is this not appropriate? You should you your judgment and class policy to decide whether to add some.

APPENDIX D – Teleconference Call Notes

The following conference call notes for the COE were taken by John Gaudet, PI, starting when he first got involved with this grant as an assistant to Dr. Jack McIver, then the Vice President for Research (VPR) at UNM. These notes demonstrate the collaboration among all participants in this COE and show the wide-ranging impact that it had on all concerned going far beyond the UNM grant, itself.

CENTER OF EXCELLENCE FOR
GAS PHASE HYBRID LASERS
CONFERENCE CALL – 26 OCTOBER 2007
NOTES

1. The following individuals took part in the COE monthly telecom of the Board of Directors: Bob Barker, AFOSR Program Manager, Jack McIver, UNM Principal Investigator, Glen Perram, AFIT Physics Professor, Scott Teare, NMT EE Professor, Roy Hamil, AFRL/RDL representative, Jonathan Stromberg, NRC Post-Doc & COE researcher/guest participant, and John Gaudet, UNM COE coordinator.
2. Bob Barker. Bob reported that he has recommended the revised budget for UNM's grant be approved. He also said that he has processed the paperwork for the next increment of funding for the COE grant. With the workload great this time of year, it may be a few weeks before these actions arrive at UNM. These actions negate the necessity to approve a no-cost extension. Jack agreed to work with NMT to ensure that their funding is received ASAP so as not to jeopardize the funding for their graduate student at the COE.
3. Scott Teare. Scott reports that five undergraduate students and one graduate student have been involved in COE projects. The concern now is that NMT needs funds within two weeks to ensure that the graduate student is not impacted. Jack indicated that UNM would find a way to provide funding for this student so that no gap occurs.
3. Roy Hamil and Jonathan Stromberg. Jonathan gave a quick summary of the three experiments that are being set up at the COE lab facility at Kirtland AFB. He described three laser systems that have shown very good slope efficiencies from 70 – 74%. Gordon Hager has been doing lifetime measurements in the laboratory, and a new NMT student is in processing the base and will be given the task of getting the DPALS lasers to laze.
4. Glen Perram. He reported that Kattie Essenhigh, NRC post-doc working on DPALS, is in the process of finishing up her work and writing papers to document her efforts. She is due to finish her assignment at the end of this calendar year. She has been given an offer from UNM to work on COE projects (see McIver discussion below on details). Glen also reported on a number of activities related to DPALS at AFIT. Greg Pitts (?) is doing experiments on absorption profiles in N_2 gas and will move on to our gases. Also, a new student now doing course work will be working in DPALS, Capt Cliff Solems (?). Glen reported on other student possibilities including graduates and undergrads that may be convinced to work on DPALS-related projects. The AFIT work will be reported on at the DEPS conference in Huntsville in a couple of weeks and at the Taos conference next April (Gordon Hager involved). Finally, he brought up the question of the exact name of the COE to be used on all papers and publicity activities. Everyone agreed that it should be "CENTER OF EXCELLENCE FOR GAS PHASE HYBRID LASERS." Bob Barker also wanted to ensure that we always give credit to AFOSR for its generous funding of the activity.

5. Jack McIver/John Gaudet. Jack discussed the Kattie Essenhigh situation. She has been given a post-doc offer from UNM and has until mid-November to consider it. We know that she has been interviewing with industry, as well. We should know her decision in a couple of weeks. Should she decide not to accept the UNM offer, Jack intends to launch a national search for a post-doc with the appropriate qualifications. If she accepts the offer, we expect her to start at UNM beginning in January 2008. John Gaudet mentioned the recent efforts to attract undergraduates at UNM. Roy Hamil, Tony Hostutler, and he spoke to the Senior Design class in the Electrical & Computer Engineering Department at UNM a few weeks ago. Word from the Professor is that three students have expressed an interest in working on a COE project. More information about these students and their project selection should be available in a week, or two. McIver/Gaudet discussed the idea of getting more publicity to attract well-qualified students. They will work on a pamphlet handout and a webpage at UNM to use for this purpose. Bob Barker mentioned the importance of expanding the funding for the COE from other agencies. This needs to be worked on sooner, rather than later. For example, if our publicity campaign bears fruit, we may have more students available than current funding would support. It was agreed that Roy Hamil, Jack McIver and John Gaudet would meet in the next few weeks to work out a strategy for new funding for the COE.

John Gaudet
UNM ECE Dept
COE Support

Notes from Teleconference
Center of Excellence for Gas Phase Hybrid Lasers
December 18, 2007

1. Individuals who were able to join us on this call were: Bob Barker, Scott Teare, Roy Hamil, Tony Hostutler, Jack McIver, Glen Perram, and John Gaudet.

2. Bob Barker comments: Jennifer Bell, contracting officer, says that new budget submitted by UNM for the COE grant is fine. *Bob will have her send an approval note via email (this has already been done).* The incremental funding can be verified by Bob via email, as well. Bob said that he would send a note about the funding delay (request has been made).

3. Regarding funding and the NMT subcontract, Jack thought that (at least partial) funding had been made. John said that the last time he brought the subject up to Roland Wildman, grant specialist that he intended to complete the subcontract ASAP. This was a couple of weeks ago. So, *Jack will talk to Roland about the NMT contract status.*

4. Roy Hamil/Tony Hostutler: Tony brought everyone up to date with the students currently working (or soon to be) at the COE from NMT and UNM. Josh Shapiro is the masters student who is looking at the physics issues on locking diodes with Gordon Hager at the COE. The NMT team of students hopes to collect data in time to present at the Taos conference (2008 High-Power Laser Ablation conference, April 21-24). The undergraduates (see attached student list) at Tech have already done a preliminary design review (PDR) on their proposal and will start experiments in January. UNM undergraduate students (see list) will work on a control system for DPALS using potassium. They have presented their ideas to the senior design class and will proceed with assembling a parts list to get started in the lab at the beginning of next semester.

5. Roy Hamil talked about the MRI kick-off meeting on DPALS recently held. He wanted the COE team to be aware that we need to be plugged into the broader area of investigations. He is concerned about students being overtaken by large, well-funded research teams in government/industry, especially for the PhD research that we sponsor. So, we need to watch out for students in this regard.. Glen P. comment: the biggest risk is the DPAL demo efforts. Spectroscopy and kinetics work is unlikely to be scooped. Scaling work, however, has quite a bit of activity underway. But, very little is being done on systematic characterization of laser performance. We should be OK there. But, we must be aggressive in our approach to the research.

6. Glen Perram: Glen requested that we put out a list of students in the minutes (This has been done). He commented that his fund status is OK for now as long as his next increment shows up in a few months. He pointed out that Tony Hostutler should be invited to participate in these telecons. This will be done in the future as all agreed. Regarding the research underway at AFIT: Kattie Essenhigh is working on two papers. Even though she has just left AFIT for GE, she will continue to work with Glen to get these papers published. The fluid mechanics paper will likely be submitted to an AIAA journal this winter. Glen then mentioned some of the other work underway by other students (see list). Some of the topics are: DPALS work on line shapes, pressure broadening, signal/noise limitations, attempting to make buffer gas measurements to within 5% or less. There is also one student involved in the theory side, but his work is slowed by the extreme accuracy needed in the input data.

7. There was a general discussion about the MRI/JTO meeting on DPALS in April in conjunction with the Taos conference. Bob Barker said to go-ahead with a COE meeting/review on April 25th even if he won't be able to make it due to a conflict in his schedule. *We should try to arrange for a speakerphone for him at the COE gathering.* We should plan to have our own meeting following the larger MRI review, perhaps later that day on Friday afternoon. *The COE should invite Howie Schlossberg and Mike Berman from AFOSR to our review* (they may be at the Taos conference). Glen Perram will be coordinating for us with the JT and Gordon Hager will be our POC for meeting facilities at Taos.

8. Scott Teare: Scott brought us up to date on the work of his students (see list) at NMT. He specifically mentioned the work being done with adaptive optics on mode corrections.

9. Jack McIver discussed the status of getting ads out for a new post-doc. Physics Today and Spectrum Magazine are two likely places we will advertise the position(s). He will send out a draft of the ad. He suggests that we look at student applications from appropriate departments during this time of the year.

10. John Gaudet: He pointed out the draft website (see location in email below) that will be used to seek out the best students for the program. We need to populate this website with more content so he asked *everyone to look it over and make suggestions and send him pictures, research descriptions, etc.* This would be an excellent place to put the research topics for each student. Glen Perram has already sent us these topics and this info will be placed on the website. *NMT and UNM should provide John with these research summaries, as well.*

John Gaudet
Research Professor
UNM

List of Students Working on COE Projects

Students from AFIT
Graduate Students:
GREG PITZ
L AARON BLANK
CLIFF SULHAM
MATT LANGE
CHRIS RICE
LUKE RODGERS

Undergraduate Student:
DOUG WERTEP

Students from NM Tech
Graduate Student:
JOSH SHAPIRO

Undergraduate Students:
JAMEY CHRISTY
ERIC MARTINEZ
TANNER OAKES
JAKE SMITH
KENDRICK WALTER

Students from UNM
Undergraduate Students:
MARIA ROSADO
WILLIAM DYTZEL
LUCUS ERVIN

AGENDA ITEMS

Gentlemen:
Here is the final agenda for today's teleconference call. I have made a few adjustments and have included the link to a proposed website to advertise the COE for students. Comments welcome!
First, the call-in number and time:
Tuesday, Dec. 18 at 1 PM MST (3 PM EST).
The call in number and passcode are:
Conference code: 1-866-713-8632
passcode: 1784547#
The draft website can be found at:
http://www.ece.unm.edu/faculty/jgaudet/COE_Web_Site/
Username: COE
Password: lasers

Here is the agenda for the teleconference call.
T = 1300 MST, 1400 CST, and 1500 EST.

AGENDA

T	Opening remarks – Bob Barker
T+0:05	COE UNM Grant/Extension/NMT contract /Laser Eye Exam Status – Jack McIver/John Gaudet
T+0:15	AFRL/RDL COE Items – Roy Hamil
T+0:25	AFIT Status – Glen Perram
T+0:35	NMT Research – Scott Teare
T+0:45	Post-Doc Status – McIver
T+0:50	Undergrad/Grad Student Search Plans – McIver/Gaudet
T+0:55	Other Items - 2008 High-Power Laser Ablation conference (25 Apr 08)
T+0:60	Adjourn

Notes from Teleconference
Center of Excellence for Gas Phase Hybrid Lasers
February 28, 2008

1. Individuals who were able to join us on this call were: Bob Barker, Scott Teare, Roy Hamil, Tony Hostutler, Jack McIver, and John Gaudet. Glen Perram was not available.

2. Bob Barker comments: Bob discussed the additional funds that have been made available to the COE to AFIT from Brendan Godfrey. He wanted Glen to share the details with everyone, but Glen was not available to do so. Bob mentioned that this extra funding (about $60K) was intended to support a student in the Dayton area to spend one year getting up to speed on a COE laser topic and another year at Kirtland working on a COE project. He suggested that Glen may be able to fill in many more details on this program at our next telecon. Otherwise, Bob reported that everything is fairly stable right now at AFOSR.

3. Scott Teare: Regarding funding and the NMT subcontract, Jack was aware that there has been funding delays for this contract. He said that funding can now be sent (freeze is over) and that he will call Scott Teare to get full details from NMT perspective. Scott explained that he urgently needs $10K to cover some COE expenses that have already occurred. Scott also reported that Josh Shapiro (NMT grad student) has delivered laser equipment from the COE to his lab in Socorro to make Rb absorption measurements. Despite a few problems associated with a rotating polarization vector, he expects that the experiment at NMT will be a success.

4. Roy Hamil/Tony Hostutler: Tony brought everyone up to date with the latest results in student recruiting. We have identified a PhD student (with a Masters in EE) at UNM that is a 90% certainty he will be starting this summer to work full time on his degree with the COE. In addition, another student, Tanner Oakes from NMT, is an excellent candidate to pursue his PhD at UNM and we have a 50/50 chance of getting him into our program. He has already been accepted in the ECE department at UNM. With many undergrads now working at the COE, possibly two graduate PhDs, and one to two post-docs, the student/mentor situation at the COE is looking up. Also, the processing of students had been taking a long time (due mostly to laser eye exam requirements) but a procedure is now in place that allows students to be able to work in the lab within a couple of weeks. Students who need access to government computers (getting a CAC + background check) will take longer.

5. Roy Hamil talked about the need to open up the research topics for the COE to a wider audience. Roy suggested that AFIT has done a great job in providing course diversity for laser students. We also might be able to take credit for some students at AFRL not now linked

to the COE. Jack agreed and that we should make a concerted attempt to attract the new batch of graduate students who will be entering in the fall semester.

6. Jack McIver discussed the status of getting a new post-doc for the COE. There is a possibility of getting a new graduate from Florida on board. There has been some difficulty in scheduling him for a visit to Albuquerque, but it looks like he will be in town during the week of 10 March. Jack has planned to meet with him then to find out what his desires are. There is also a possibility he could be picked up as an NRC Fellow, in which case his first year cost would be picked up by that program.

7. John Gaudet: Finally, John discussed the status of getting a website to assist in recruiting for the COE. This is turning out to be a coordination-heavy task with Kirtland. He talked with Jan Bush at AFRL about this at Tony's suggestion. While she was very willing to help with this (and even suggested some improvements to the draft pages/forms already done), she is strongly suggesting that Kirtland host the pages since all AFRL-related items have to approved by Public Affairs and undergo an OPSEC review anyway. She also thought that we would get many hits through an AFRL host. However, in discussing this with Bob and Pat Helles (a UNM CHTM employee who has worked with Bob on websites in the past), there would be many potential problems with the Air Force as host. A compromise solution has been proposed (by Bob). We can have the base host a website that talks only about the COE and AF facilities and research underway (needs approval anyway). A link will be provided on that site to a UNM-hosted site that talks about the recruiting process at UNM and NMT. This site can easily provide CGI-based online forms for the potential students to fill out. In this way, a database can be automatically maintained of contact info. (This would likely not be possible on an AF-hosted site due to security concerns with CGI forms). In this way, no AF approval will be required for the UNM hosted site since it will only be about recruiting students. Everyone thought this was a good idea, and John will pursue it.

8. The review for the COE is still set for Friday, April 25th in Taos, NM at the end of the 2008 High-Power Laser Ablation Conference. Gordon Hager and Glen Perram are working this. Bob suggested that if it is too expensive to get a speaker phone for the room, we shouldn't bother with it since he may not be able to join us from CA anyway. I have included the username and password for the website. Please look this over from time-to-time as I will be updating it. The next big change should incorporate this new approach so it will concentrate on student recruitment activities.

John Gaudet
Research Professor
UNM

List of Students Working on COE Projects

Students from AFIT
Graduate Students:
GREG PITZ
L AARON BLANK
CLIFF SULHAM
MATT LANGE
CHRIS RICE
LUKE RODGERS

Undergraduate Student:
DOUG WERTEP

Students from NM Tech
Graduate Student:
JOSH SHAPIRO

Undergraduate Students:
JAMEY CHRISTY
ERIC MARTINEZ
TANNER OAKES
JAKE SMITH
KENDRICK WALTER

Students from UNM
Undergraduate Students:
MARIA ROSADO
WILLIAM DYTZEL
LUCUS ERVIN

AGENDA ITEMS

Gentlemen:
The next conference call for the Center of Excellence will be:
Thursday, Feb. 28 at 10 AM MST (12 PM EST)
The call in number and passcode are:
Conference code: 1-866-713-8632
passcode: 1784547#
The draft website can be found at:
http://www.ece.unm.edu/faculty/jgaudet/COE_Web_Site/
Username: COE
Password: lasers

Here is the agenda for the teleconference call.
T = 1000 MST, 1100 CST, and 1200 EST.

AGENDA

T	Opening remarks – Bob Barker
T+0:10	COE UNM Grant/Extension/NMT contract - Jack McIver/John Gaudet
T+0:15	AFRL/RDL COE Items – Roy Hamil/Tony Hostutler
T+0:25	AFIT Status – Glen Perram
T+0:35	NMT Research – Scott Teare
T+0:45	Post-Doc/New Student Status (Cary Henry Visit, etc.) – McIver
T+0:50	Taos Review – All
T+0:55	Website Update – Gaudet
T+0:60	Adjourn

Notes from Teleconference
Center of Excellence for High Energy Lasers*
April 7, 2008

1. Individuals who were able to join us on this call were: Bob Barker, Scott Teare, Roy Hamil, Glen Perram, Tony Hostutler, Jack McIver, Tom ~~Shea~~ Shay and John Gaudet.

2. Bob Barker comments: Bob wanted all to know that there is a high level of interest in the COE at AFOSR and elsewhere in the Air Force from management. From Brendan Godfrey on down, all think the COE is a great concept and want to see it succeed. Jack McIver added that President Schmidly of UNM has also become aware of the COE and is enthusiastic about the concept. He heard about the COE on a recent visit to Kirtland AFB.

3. Jack McIver: Jack announced that since he will be leaving UNM by June 1st, he will need to recommend a new PI for the UNM grant to Bob. This is necessary since it does not make any sense to take this type of grant with him to Idaho. He hopes to have a recommendation by the end of this week, or the beginning of next week (14-18 April).

4. *Name Change: After a brief discussion, the Board of Directors for the COE agreed to a name change and an expansion of the research areas for students with the COE can pursue. From now on, the center will be known as the "Center of Excellence for High Energy Lasers." With this name change and the expansion of the topics to include all high energy laser concepts, other students at AFRL working on degrees at AFIT, UNM and elsewhere become eligible for inclusion in the COE.

5. Roy Hamil/Tony Hostutler: Tony briefly mentioned the student group projects underway at the COE with NMT and UNM undergrads. The UNM students are working on a control system and the NMT students have recently tried to take data last week but had contamination issues. They have learned some interesting features of the experiment, however. Tony and Gordon Hager are working with the students to prepare talks for the upcoming Taos meeting. Josh Shapiro's masters topic is also going well at this time.

6. Glen Perram: Glen updated everyone on the status of new AFOSR money just received by AFIT to recruit more students for COE projects. He is seeking out local Dayton-area students who would attend AFIT for 9 months to receive basic graduate courses and get a start on their research topic. They would then move to Kirtland AFB and the COE to continue/finish their project and complete course work at UNM. He currently has three individuals in mind who have expressed interest in this new program and will speak personally to them soon. Two are undergrads at Ohio State and Cederville College and one is a M.S. grad from University of Akron who would be seeking a PhD. Glen also mentioned that a JTO review of the MRI (COE would be part of review) will take place in Albuquerque on May 8th at the

Pyramid Hotel. Attendance is by invitation only; Roy said he could get anyone interested in attending an invite. Finally, Glen noted that he would be bringing one of his students to the Taos meetings (Greg Pitz).

7. Scott Teare: Tony Hostutler already reviewed Scott's student activities at the COE. Scott did indicate that all of the paperwork for the subcontract with UNM has been processed at NMT and they are awaiting UNM action. Jack McIver said that he would immediately check into the paperwork status.

8. Jack McIver/Tony Hostutler announced that Nate Zamorski has officially accepted the UNM COE grant offer to pursue the PhD at UNM working on a COE project. Tony mentioned that Nate is currently considering two topics and will select one soon. He will finish his employment at SNL in June and start up at AFRL by the end of that month. He should be able to quickly add the courses he needs and fast track his way towards a degree at UNM.

9. John Gaudet: John again discussed the status of getting a website to assist in recruiting for the COE. The AFRL Business Office folks have assisted him in preparing a pamphlet which will be used to distribute and to get approval for web pages for the same info from Public Affairs. A draft of the pamphlet was circulated to the COE Board of Directors. Comments received suggested that the focus on education wasn't strong enough and the pictures were not eye-catching. At the same time, the idea of a name change and enlargement of the scope of the COE was brought to the table for discussion. Since we have agreed to the expanded scope, the pamphlet will be revamped so that it emphasizes the educational aspects of the COE. Much more information about the other institutions will be included in all four pages of the brochure (NMT, UNM, and AFIT). Therefore, John urged everyone to search their files and provide pictures and text that would be suitable for inclusion.

10. The review for the COE is set for Friday, April 25th in Taos, NM at the end of the 2008 High-Power Laser Ablation Conference. Gordon Hager and Glen Perram are working this. Bob indicated that due to a busy travel schedule on this day, he will not be able to participate by conference call at our meeting from 1 – 4 PM on April 25th. Jack McIver suggested that the three objectives of this afternoon COE session should be: (1) Technical items not brought up elsewhere during the week about COE topics, (2) Future research directions for the COE, and (3) Business items. John agreed to draft an agenda and send it out for review/comment in the next week, or so.

John Gaudet
Research Professor
UNM

List of Students Working on COE Projects

Students from AFIT
Graduate Students:
GREG PITZ
L AARON BLANK
CLIFF SULHAM
MATT LANGE
CHRIS RICE
LUKE RODGERS

Undergraduate Student:
DOUG WERTEP

Students from NM Tech
Graduate Student:
JOSH SHAPIRO (MS)

Undergraduate Students:
JAMEY CHRISTY
ERIC MARTINEZ
TANNER OAKES
JAKE SMITH
KENDRICK WALTER

Students from UNM
Graduate Student:
NATE ZAMEROSKI (PhD)

Undergraduate Students:
MARIA ROSADO

WILLIAM DYTZEL
LUCUS ERVIN

AGENDA ITEMS

Gentlemen:

The next conference call for the Center of Excellence will be:

Monday, April 7th at 11:30 AM MDT (1:30 PM EDT)

The call in number and passcode are:

Conference code: 1-866-713-8632
passcode: 1784547#

Here is the agenda for the teleconference call.

T = 1130 MDT, 1230 CDT, and 1330 EDT.

AGENDA

T	Opening remarks - Bob Barker
T+0:10	COE UNM Grant PI Change - Jack McIver
T+0:15	COE Name Change - All
T+0:25	AFRL/RDL COE Items - Roy Hamil/Tony Hostutler
T+0:30	AFIT Status - Glen Perram
T+0:35	NMT Research - Scott Teare
T+0:40	Post-Doc/New Student Status - N. Zameroski - McIver
T+0:45	Taos Review Preparations- All
T+0:55	Website/Pamphlet Update - Gaudet
T+0:60	Adjourn

Notes from Teleconference
Center of Excellence for High Energy Lasers
June 24, 2008

1. Individuals who were able to join us on this call were: Scott Teare, Roy Hamil, Glen Perram, Tony Hostutler, Wally Clark, Bob Duryea (RVOT) , and John Gaudet.

2. As Bob Barker was not able to make the conference call, we adjusted the agenda a bit and started with reports from AFIT and NMT.

3. Glen Perram: Glen gave a brief report on AFIT DPALS work and student status. Paul Jones from Ohio State has just arrived at AFIT and will begin to take courses in the fall. AFOSR provided funding for this student through a special grant. Half of his time will be spent at AFIT and then he will move to NM next summer to do research at the COE and complete his coursework at UNM. Glen will contact UNM/John Gaudet as soon as he has a chance to review the academic plan with Mr. Jones. Also, Glen reported that Gordon Hagar and he recently went to LLNL to review DPALS work at General Atomics and at LLNL. There may be some aspects of this work that AFIT will be able to help out with. For example, 2nd order kinetics processes, and nonlinear optics processes that produce ionization in the alkalide gases. The new student, Paul Jones will be looking at this. Major Cliff Sulham (PhD candidate) is working on a scaling experiment. His research requires a Ti(Saphire) laser that is being procured by RDL. As he will have only limited time to conduct his research, the experiment needs to be

ready to go when he arrives at Kirtland. Right now, there is a hold up in delivery of the laser due to specs not being met. Gordon and Tony will travel to Boulder, CO next week to check on status with the manufacturer. They hope to have all laser issues resolved by late summer/early fall in time for Major Sulham's arrival.

4. Scott Teare reported on NMT activities: On the experimental side, undergraduate Vanessa Salas is working at the COE and is interested in pursuing a PhD in physics. Josh Shapiro is working on data acquisition/control systems for DPALS, going after mode hoping issues. His approach is a bit more complicated than that of the UNM undergraduates that worked on these same types of issues during the spring semester. Josh will be presenting his thesis proposal tomorrow at NMT. Scott is looking into getting students from the Physics Department through its chairman, Dave Westphal. Basically, all is going as planned for NMT with COE activities, thus far.

5. I made the announcement that UNM (interim provost) had recommended me (JG) as the sole-PI for the UNM grant, replacing Jack McIver. Also, Bob Barker had quickly endorsed this selection last week.

6. Tony Hostutler for RDL and the COE: Nate Zameroski, our first PhD student, has just showed up at the COE. He will be working with Prof. Wolfgang Rudolph in the Physics Deparatment at UNM. He will finish his in-processing on the base quickly and should be able to start collecting data in a few weeks as his experiment is ready to go. Vanessa Salas is working on examining the losses in DPALS, from off windows etc., taking careful measurements and then will match her results with theoretical calculations. Josh Shapiro is working on locking issues, as mentioned above. Tony mentioned a bit more detail on the Ti-Sapphire laser that they are in the process of buying. The biggest problem is that it hasn't met the specs for the line width, showing 100 GHz instead of 20 GHz. Tony also told us that a "Lab TV" snippet for the COE is under development with Jan Bush in the business development office. It was pointed out by Roy Hamil that Tom Shea has up to seven students working on HEL projects that we need to find out about and include them into the reporting of COE activities if appropriate. I (JG) will contact Tom Shea (ACTION) for details on all his students.

7. Glen Perram: Glen brought up the issue of AFOSR (Godfrey) not being satisfied with COE progress and that he wants AFRL to propose solutions to the problems that he sees. It is his understanding that AFOSR is waiting for a satisfactory reply or funding withdrawal could take place. I pointed out that Bob Barker and I (JG) have discussed "get well" plans and that I would be directing any discussions to him on this matter as the Program Manager from AFOSR for this grant. After some discussion, it was decided that RDL (Tony and Wally) would contact Brendan Godfrey about what he requires from them on the COE's future. They will email/call him to get a list of questions that BG wants answered and then Tony will draft a reply and send it around to all on the board of directors for the COE (ACTION: TH).

8. Scott Teare: Scott suggested that the funding timelines for grants in terms of start/stop times for the government poorly match with universities needs in student support. Wally agreed that this was a problem and he will include this issue in RDL's response to AFOSR.

9. Glen Perram: Glen pointed out that it would be useful to find out what AFOSR's timeline for funding of the COE is? That is, will AFOSR now only fund the COE through FY09, or beyond?

10. Wally Clark: Wally asked Glen Perram about the MIPR status that they had sent to AFIT in terms of spend rate. Glen had sent Tony details on status just yesterday. Some options were mentioned by Glen as to how the low spend rate could be addressed. I pointed out that this problem is similar within UNM in terms of demonstrating funds expended on the COE grant.

11. Finally, I briefed everyone on the status of the COE pamphlet that the RD business development office is preparing. Due to uncertainties in the PI status at UNM, I had requested that Jan Bush put the pamphlet on hold for a little while. Now that the PI issue is resolved, we will make final adjustments and get everyone a (final) draft of the pamphlet for review.

12. The next COE teleconference call will be late July. Details to come.

John Gaudet
Research Professor
UNM

List of Students Working on COE Projects
(Needs Updating?)

Students from AFIT
Graduate Students:
GREG PITZ
L AARON BLANK
CLIFF SULHAM
MATT LANGE
CHRIS RICE
LUKE RODGERS

Undergraduate Student:
DOUG WERTEP

Students from NM Tech
Graduate Student:
JOSH SHAPIRO (MS)

Undergraduate Students:
JAMEY CHRISTY
ERIC MARTINEZ
TANNER OAKES
JAKE SMITH
KENDRICK WALTER
VANESSA SALAS

Students from UNM
Graduate Student:
NATE ZAMEROSKI (PhD)

Undergraduate Students (FINISHED SENIOR DESIGN PROJECT IN MAY 2008)
MARIA ROSADO
WILLIAM DYTZEL
LUCUS ERVIN

AGENDA ITEMS

Gentlemen:
The next conference call for the Laser Center of Excellence will be:
Tuesday, June 24th at 9:30 AM MDT (11:30 AM EDT)
The call in number and passcode are:
Conference Call-In #: 1-888-469-3352
passcode: 68666
Here is the agenda for the teleconference call.
T = 0930 MDT, 1030 CDT, and 1130 EDT.

AGENDA

T	Opening remarks – Bob Barker, PM
T+0:05	COE UNM Grant PI Change - Bob Barker
T+0:10	Status of UNM Grant - Gaudet
T+0:20	AFRL/RDL COE Items – Roy Hamil/Tony Hostutler/Wally Clark
T+0:30	AFIT Status/RDL Collaboration/Research – Glen Perram
T+0:40	NMT Status/Student Prospects/Research – Scott Teare
T+0:50	Website/Pamphlet Update – Gaudet
T+0:55	Upcoming Events – Gaudet/All
T+0:60	Adjourn

Notes from Teleconference
Center of Excellence for High Energy Lasers
August 13, 2008

1. Individuals who were able to join us on this call were: Robert Barker, Scott Teare, Roy Hamil, Glen Perram, Tony Hostutler, Luke Lester, Craig Robin and John Gaudet.

2. Bob Barker: Now is a crucial time for the Center. The next few months will be essential in demonstrating COE progress. In addition, Bob reminded all that the annual report for the COE is due on 31 August. This year, he would like to submit a consolidated report including the activities of AFIT, NMT and UNM. John Gaudet will be the editor of the report which should include all the latest research and results in the form of publications, students involved in the COE, and general progress in the standing up of the Center. In order to put as much substance into the report, we should feel free to go over the 200 word limit normally imposed in the "Status of Effort" section.

3. John Gaudet: Briefed everyone about the status of the UNM COE grant. He is the new PI on it and has been working with Bob Barker on a revised plan to extend the grant through FY10. He will be submitting to AFOSR two requests. An immediate request to procure some needed equipment for newly acquired students/projects in the UNM Physics and ECE Departments, and a complete revision of the budget to accurately reflect the current resource status and future spending. More on this "get well plan" later in the teleconference. John also introduced Luke Lester from the Center for High Technology Materials (CHTM) in the ECE Department who has new students/projects for the COE.

4. Luke Lester: His two student projects involve mode-locked semiconductor lasers. One student has been found for this research and another potential PhD candidate is just finishing up his Masters' degree with Luke. They will be integrating the semiconductor lasers with fiber amplifiers to create high energy peak power lasers. The students will be learning and working about the fiber amplifiers and fiber lasers and the best way to integrate them with the devices that Luke makes in his lab. One specific research topic will be on pulse compression and the other will be on integrating the diode laser with fiber amplifier. The wavelength range should be from 1200 – 1300 nm. Luke also pointed out that UNM has just acquired a Fiber Draw Tower which is located at the CHTM facility. This is a rather unique piece of equipment which can be used to generate fibers of specific design and doping characteristics. It should be available at UNM in a few months for use by students and AFRL on these joint research projects. Luke plans to have at least one of his COE students use the tower during his research.

5. Tony Hostutler: There has been lots of student activity during the summer, thus far, at the COE. The (SMART) student has gone back to BYU, having successfully completed pressure broadening experiments during which he took a lot of data to analyze. Josh Shapiro from NMT has also studied loss mechanisms and pressure broadening. Nate. Zameroski, UNM, has hit the ground running. He has already made progress towards setting up his experiments for his dissertation. The only bad news that Tony had to report is that although the new TiS laser has arrived, the pump laser for it died. They hope to have it fixed by next week. This laser will be used by one of Glen Perram's students as soon at it is deemed operational.

6. Roy Hamil: discussed the idea of a review of the COE from the AFRL perspective. There has been some discussion between the Chief Scientist, Director, and AFOSR director about conducting such a review. However, all of these people are heavily involved in preparing the Directed Energy Directorate for an SAB review in November. Bob Barker says that it's unlikely a review would be conducted before December and that it could be postponed until after the first of the year. Roy also indicated that expansion of COE concept is possible. There appears to be a lot of discussion about needing to fill the gap that is occurring in trained scientists/engineers in the directed energy fields at AFRL. Our COE could become the model program to deal with this pending problem.

7. Craig Robin: Craig is a student at UNM in the ECE department working under the guidance of Tom Shay at AFRL. He is also an AFRL employee. There are several UNM students in this category (see list at the end of these notes). They are working on the solid state side of the laser program. Major experiments underway are involved with a coherent combination of fiber amplifiers. Issues being addressed include power scaling of the fiber amplifiers, front-end work, and modeling & simulation. See the list of projects below. All of these topics are tied together. Craig mentioned that there may be a future effort with the SOR laser in terms of replicating it. Luke Lester agreed that he would meet with Tom Shay's students soon to discuss this opportunity.

8. Glen Perram: Glen updated us on the status of the AFIT COE work. Paul Jones is the student selected to spend time at both AFIT and Kirtland. He is an OSU graduate and has started doing some DPALS experiments at AFIT this summer. Glen will send John Gaudet an education plan that will include taking some classes at UNM. These classes need to be identified. Glen has been working with Gordon Hager and LLNL on the subject of energy pooling. Matt Lang who was Glen's PhD student has finished his dissertation and is looking for employment. He could be a candidate for a post-doc position at Kirtland. Tony Hostutler will look into this. Glen reports that they have addressed and possibly solved the problem of being able to vary the pressure in a cell. Gregg Pitts reported preliminary work on this at the Taos meeting. Cliff Sulham will be working on the TiS laser at Kirtland COE for the laser demo work. He also reported on a problem with laser power being down from original specification. The pump source is not as robust as estimated so they are only getting half

power. They do get a gtood quality beam, though. Grady Phillips is at AFOSR was Glen's student. He has applied for a six-month study program where he will work at AFIT. Matt Rodendaro (sp?), a retired LtCol, is anxious to do science with AFIT, He lives in Colorado Springs right now and may help with some USAFA collaborations. Glen is continuing to work on journal article with Gordon Hager and it should be ready soon. Glen will be coming to Albuquerque to teach a short course during the week of 8 September. We discussed plans to get RDL, AFIT, UNM, NMT together during the week to strategize on preparing proposals for future funding of the COE.

9. Scott Teare: Josh Shapiro is finishing up his thesis and will present the results at the AMOS conference in Maui next January. Scott also reported that he is concentrating on recruiting students. He has two possible new students. One will be an M.S in EE (Ed Schuler). The other is a potential PhD student in Physics (Tom).

10. John Gaudet: John summarized the get-well plan he has begun to implement for the AFOSR COE grant. It is centered on a new research area, fiber lasers, and a new faculty member, Luke Lester. Luke has already identified two new students that should be on board with COE research. In order to implement this plan some new equipment will be needed for the COE. The result will be that by the end of the current grant period (30 Nov 08), there will be approximately one year's funding left in the grant. Therefore, a budget revision will be requested from AFOSR to reduce funding in FY09 to only the amount needed and to extend the grant with the final option dollars into FY10. This will put the students on the grant, the research, and the resources in sync.

John Gaudet
Research Professor
UNM

List of Students Working (and Recently Finished) on COE Projects

Students from AFIT
Graduate Students:
GREG PITZ
L AARON BLANK
CLIFF SULHAM
MATT LANGE
CHRIS RICE
LUKE RODGERS

Undergraduate Student:
DOUG WERTEP

Students from NM Tech
Graduate Student:
JOSH SHAPIRO (MS)

Undergraduate Students:
JAMEY CHRISTY
ERIC MARTINEZ
TANNER OAKES
JAKE SMITH
KENDRICK WALTER
VANESSA SALAS

Students from UNM
Graduate Student:
NATE ZAMEROSKI (PhD)

Undergraduate Students (FINISHED SENIOR DESIGN PROJECT IN MAY 2008)
MARIA ROSADO
WILLIAM DYTZEL
LUCUS ERVIN

Students at UNM working for Tom Shay

CRAIG ROBIN, PhD candidate in optics, Novel photonic crystal fibers for single frequency fiber amplifiers

CHRIS VERGIEN, MS Candidate in optics, Power scaling limits of current single frequency photonic crystal fiber amplifiers

CHUNTE (ANDY) LU, MS Candidate in optics, All-fiber isolators for high power operation

BENJAMIN PULFORD, PhD candidate in optics, Novel applications of phased arrays of fibers

MICHAEL ZMUDA, PhD candidate in optics, SBS mitigation in optical fiber amplifiers

Student at UNM working with Luke Lester
FURQAN CHIRAGH, MS and future PhD candidate, mode locked semiconductor lasers

AGENDA ITEMS

T	Opening remarks – Bob Barker, PM
T+0:05	UNM Grant/New Students & Projects – Gaudet/Lester
T+0:15	AFRL COE Items/Review(?) – Tony Hostutler/Wally Clark/Roy Hamil
T+0:25	AFIT Status/RDL Collaboration – Glen Perram
T+0:35	NMT Research Status – Scott Teare
T+0:45	UNM Get Well Plan – Gaudet
T+0:55	Miscellaneous (upcoming meetings, publicity, etc.) – Gaudet/All
T+0:60	Adjourn

Notes from Teleconference
Center of Excellence for High Energy Lasers
October 27, 2008

1. Individuals who were able to join us on this call were: Robert Barker, Scott Teare, Roy Hamil, Glen Perram, Tony Hostutler, and John Gaudet.

2. Bob Barker: Bob informed us as to status of duration of grant issue. Since the first year of COE grant got off to a slow start, resources have been carried over each year. So, with the objective to give more time for the COE grant to graduate students at minimum cost to the Air Force, UNM made a request to re-budget the grant with a new end date of July 2010. This should give everyone time to allow the grant activities to take hold and to extract real benefits from center. Also, the additional time will give the research participants an opportunity to put together follow-on proposals and to grow opportunities which come from the research. The requests from UNM to AFOSR will achieve these objectives. Bob has had discussions with his procurement people about this plan to increase the duration of the grant by 12 months for a modest sum. So far, everything looks positive for implementation. In the meantime, Bob has requested that the increment to start on 1 Dec 2008 be approved (with the minimum funds added) so that UNM will not have to stop work at the end of November.

3. Bob also discussed Luke Lester's visit to his office last week. He found Luke to be very enthusiastic about the COE and believes that he (and his students) will be a welcome addition to the COE team for the Air Force.

4. I discussed the UNM students working at the COE, mostly about Nate Zameroski, who is turning out to be a model student for the COE. He is extremely motivated to graduate. Nate presented a seminar at UNM last week and did a very nice job explaining the purpose of his research and his progress. (His seminar presentation is attached to these notes.) He will soon be presenting his PhD proposal to his committee and will be adding as much support data as he can to the proposal in the coming days. Tony Hostutler also described this work and the efforts of COE personnel in getting prepared for the Science Advisory Board (SAB) visit in early November. The SAB, in fact, was at the COE inspecting the facilities a few weeks ago. Tony also mentioned that the COE got its new Ti-Saphire laser to show first light last

Thursday. All they now need are new heater blocks for the laser to get it fully operational. This piece of equipment is critical for AFIT's student (Cliff) who will be doing scaling measurements (demonstration experiment). The anticipated operational date is mid-Nov.

5. Roy Hamil said that the twelve month reprieve for the grant is good news regarding the need to identify new sources of funding. This extra time is needed to get proposals written and funded to ensure students may continue in the pipeline for the COE.

6. Glen Perram: The JTO MRI review took place in Albuquerque two weeks ago. It included the new DPALS work that is underway at AFIT, NMT and the COE. Glen said that the feedback he heard at the review was very positive for this research, especially the academic portion of the tasking. He is seeking out any other individuals who were present at the review for feedback. Roy Hamil said that he had heard the same type of comments. Glen has provided us with a copy of his presentation at the MRI review and it is attached to these meeting notes. Glen also reiterated that Cliff S. will be doing the demo experiments soon at AFRL. They are excited about pushing the pump rate above threshold for these experiments. Finally, AFOSR has sent one if its employees to AFIT for a six-month exchange program. He is already at AFIT now and beginning to collect data in the lab.

7. Scott Teare: Scott has been working under the assumption that his subcontract will end on Nov. 30th of this year (as he must) and has carefully been using students accordingly. With the news that Bob Barker provided us today, however, it may be possible to actively recruit students for the COE from NMT once more. John Gaudet will discuss these options with Scott at NMT this Wednesday. Josh Shapiro has collected a lot of data at the COE that he's currently analyzing. He hopes to defend his masters' degree in mid-November. Afterwards, he'll be going to CA for grad school. Schuler (sp?) is new student that is getting up to speed on the equipment so far this semester. Also, Vanessa Salas (undergrad) is also still working on the COE project. Finallym, Scott reported that they believe a paper or two can be prepared from Josh's work. He did present a preliminary version of it at the AMOS meeting in Maui last month.

8. Roy Hamil did ask about the status of the solid state laser projects under the lead of Tom Shay, RDL. These projects are now considered part of the COE effort. In fact, Tom Shay will be closely collaborating with Luke Lester at UNM on his students' projects. They plan to meet in November to discuss these activities.

9. I updated everyone on the status of the COE UNM website, pamphlets and participation in the Education Workshop at the end of the DEPS Symposium in November. The UNM Website is now being developed by a professional webmaster from CHTM. I hope that it will be available by mid-November. It's function will be to have a public space for recruiting interested students and a private area to post work-in-progress, presentations, results, data exchange, etc. The official first COE pamphlet from AFRL has been published and everyone should have copies. It is approved for public release by the Air Force. It can be used to aide in recruiting students and professors, and getting the word out about the COE. I will be making a pitch for the COE and the Education Workshop in mid-November. I will also use the pamphlets (and hopefully the website) to discuss who we are and what we want to do.

John Gaudet
Research Professor
UNM

AGENDA ITEMS
October 27, 2008

T	Opening remarks – Bob Barker, PM
T+0:05	UNM Students & Projects – Gaudet/Tony Hostutler
T+0:15	AFRL COE Items – Tony Hostutler/Roy Hamil
T+0:25	AFIT Status/RDL Collaboration – Glen Perram
T+0:35	NMT Research Status – Scott Teare
T+0:45	UNM Grant Status/extension – Gaudet
T+0:55	Miscellaneous (upcoming meetings, recruiting, website, etc.) – Gaudet/All
T+0:60	Adjourn

Notes from Teleconference
Center of Excellence for High Energy Lasers
February 5, 2009

1. Individuals who were able to join us on this call were: Robert Barker, Scott Teare, Roy Hamil, Glen Perram, Tony Hostutler, Wally Clark, Wolfgang Rudolph, Luke Lester, and John Gaudet. Tom Shay was unable to call-in.

2. Bob Barker: Bob informed us as to status of the extension. He said the best news of the new year was that we got off to a good start with approval of the UNM grant extension. Wally asked about the details of the extension. John indicated that the grant received another year (until July 2010). The funding added was minimal ($31K) since resources were still available from previous years. Bob wanted to establish continuity to the teleconferences so he asked for ideas for the next one. Since the weeks of 9 March and 23 March are bad, the week of 16 March is a likely candidate. John will work towards setting it up then. John mentioned the need for a face-to-face meeting of COE scientists and professors so new proposals can be started. The next few conferences where such a side-meeting may take place are: the DEPS Directed Energy Systems Symposium, April 6-10, in Monterey; the DEPS HEL JTO Annual Review in Albuquerque, May 4-8; and the CLEO/IQEC 29th Conference on Lasers and Electro Optics and the 27th International Quantum Electronics Conference in Baltimore, May 31-June5. Regardless of where our meeting is held, Wally suggested that JTO folks be invited. Glen Perram has the Baltimore meeting high on his priority list to attend. Others from the COE are likely to be there, as well. John will work on scheduling a meeting as soon as practical at best location.

3. John Gaudet gave a few more details on the COE grant extension from UNM's perspective. All of the paperwork for the extension to UNM and the subaward to New Mexico Tech is essentially complete.

4. Tony Hostutler next told us about Nate Zameroski's PhD thesis work. Nate has completed his proposal defense in December and has taken a good deal of data that is in the process of being analyzed in the DPALS facilities of the COE at Kirtland AFB.

5. Luke Lester introduced us to two new COE students (both PhDs). Furqan Chiragh and Nish Patel are getting their paperwork finished to start working in the laser fiber testbed facility at the COE, Kirtland. They hope to conduct research on compressing fast laser pulses to produce higher powers. Luke expects they will require 4-6 months of apprenticeship work at RDL to get familiar with the experiments and equipment. Luke is very pleased with this opportunity to collaborate with RDL on research topics and to have access to RDL equipment his students wouldn't normally have which can do a better job in these investigations.

6. Glen Perram updated us on trip of Cliff Sulham to Kirtland in order to use RDL's new laser to conduct his DPAL scaling demonstration experiments. He did this two weeks ago with 4-day work week. These experiments extended the output power to 18-times threshold, greater than anything else achieved to date. They would like to extend this work in the future. They will do more pulse experiments at AFIT and, perhaps, other experiments at RDL, as well. Major Philips has recorded the hyperfine structure in the D2 line in rubidium and is pushing on to more experiments. Paul Jones will be coming to KAFB end of summer to conduct glow experiments. He has data on the spectrum and is characterizing it. Glen did mention that he has no current plans to add COE students since his plate is pretty full now. However, see comments below from Roy Hamil.

7. Scott Teare. Scott talked about Josh Shapiro's successful completion of his masters' degree at NMT and is the first graduate of the COE grant. He is in a position of rebuilding the COE grant students this semester. He hopes to interest some promising undergraduates with the COE work. He'll try to get them to Kirtland this semester. Tony H. offered to go back down to NMT and give a seminar about our work. Then, he may be able to recruit students for graduate programs starting in the fall (or summer). Lastly, Josh's work is being prepared as a paper for publication in a refereed journal.

8. Wolfgang Rudolph told us about some new equipment for COE students recently acquired. The main component is a new Q-switched ns laser which will pump the Physics Department's OPO to explore tri-atomic gases for lasing. Luke Lester also mentioned his new equipment. He received a real-time measurement capability with an 80 GHz sampling scope. This greatly improves his capability to measure the compression of his laser pulses. Other new equipment (FROG) allows for the accurate measurement of pulse compression. Thus, he gets the ability to do chirp pulses and to see higher peak power in devices with FROG (for accuracy) and to acquire data much more quickly (with digitizing scope).

9. Bob Barker suggested that we investigate the possibility of using NSF's STC (Science & Technology Center) program for possible future source of funding. Info about it can be found at: http://www.nsf.gov/od/oia/programs/stc/. This competition is run by the NSF Office of Integrative Activities.

10. Tony Hostutler provided some good news about a possible postdoc candidate for the DPALS COE labs. Sheldon Wu will receive his PhD in May. He has been working on his dissertation at LLNL and is interested in doing a postdoc somewhere else once he graduates. He would

likely compete favorably in an NRC competition. Or, he could be hired as a postdoc from UNM to work at RDL (similar to what Jonathan Stromberg did in 2007). Tony will pursue this action and keep us posted.

11. Wally Clark. Wally mentioned that he soon hopes to announce their new senior technical advisor in RDL who will help with COE future planning. Related to this, Bill Baker, AFRL/RD's chief scientist, has indicated that a new ST position will be created for RDL. Wally would like to participate in all of our teleconference calls in the future.

12. Roy Hamil mentioned that Glen Perram's student who may work on a beam control topic should be considered as a COE student since we have opened up the COE to all high energy laser areas. Glen thinks this is a good idea. More to come on this next time.

13. John mentioned Tony's idea to start a COE student seminar program in Albuquerque so that all the variety of research topics can be shared among them and RDL. John will work on getting this going.

14. John updated everyone on the status of the UNM COE website. In is in development, but not quite ready for pubic use. The emphasis of the site will be a bit different than originally planned. Now, a significant portion of the site will be a private area where COE members can share proposals, draft papers, upcoming events calendar, planning of future activities, etc. This site will hopefully be ready soon, by the next conference call.

15. Finally, John mentioned that he will be retiring from UNM effective 1 April. He will continue on as PI for the grant in a part time (25%) capacity, however.

John Gaudet
Research Professor
UNM

AGENDA

THURSDAY, FEBRUARY 5, 2009

T= 12:30pm (PST), 1:30pm (MST), 3:30pm (EST)

T: Opening Remarks --- Bob Barker

T+5: Status of grant extension --- John Gaudet

T+10: Current UNM student activities --- Tony Hostutler

T+15: AFIT students progress --- Glen Perram

T+25: NMT student status --- Scott Teare

T+30: New/Future students: UNM (Lester), NMT (Teare), AFIT (Perram), AFRL (Shay)

T+45: Miscellaneous items
- new equipment for COE/plans
- website
- follow-on funding
- new student recruiting
- postdoc opportunity
- Grant PI status

Notes from Teleconference
Center of Excellence for High Energy Lasers
April 16, 2009

1. Individuals who were able to join us on this call were: Scott Teare, Roy Hamil, Glen Perram, Tony Hostutler, Wolfgang Rudolph, Luke Lester, Tom Shay, Eugene Bednarz and John Gaudet. Bob Barker and Wally Clark were unable to call-in.

2. John Gaudet explained that this was a targeted conference call to talk about the upcoming May 6th meeting at the Marriott Pyramid Hotel in Albuquerque. He pointed out the "strawman" agenda that he sent to everyone prior to the call as a starting point for our discussion today.

3. Here is a summary of the one hour discussion:

    a. It was quickly decided that we should consider all options for securing the future funds for students beyond 31 July 2010. That is, individual professor proposals, joint efforts among several faculty members from one, or more, universities, and an umbrella proposal for UNM/NMT/AFIT funding for fellowship support.
    b. Luke Lester will get together with Glen Perram and Tom Shay to sketch out what the future for his area (sensors, etc.) will look like. Scott Teare will also provide us on May 6th with his thoughts.
    c. We discussed whether we should invite participation in our meeting from others not directly involved in the COE funding decisions. The decision was made not to do this for such a targeted meeting. However, even though it is likely that Harro Ackermann will be present representing JTO, some believe that Don Seeley should also be invited from JTO since he is running the grant with DEPS for student fellowships.
    d. Options for proposals that were mentioned include proposing to DEPS directly (see above), getting small business to participate in COE proposals, and adding other institutions to our list of those who participate in the COE student suppliers. The last option was eventually nixed due to the way the COE charter reads and the enormity of the task for the existing setup and challenges to bring in other players for the May 6th meeting. Adding small business as an option was briefly discussed. Some pointed out that it could be complicated by proprietary issues and the brief nature of vehicles such as Phase I SBIRs/STTRs.
    e. Ultimately, we all agreed that for the May 6th meeting we should concentrate on the existing team of players (UNM/NMT/AFIT). We should have as a goal to come out of the May 6th meeting with a clear plan to proceed with proposals that take us beyond the current AFOSR grant.
    f. Regarding JTO funding, Glen mentioned that he currently has an MRI task that involves several universities. This example could be a model for our proposals to JTO, AFOSR, or other funding agencies. We should find out from JTO when their next MRI Call for Proposals will be issued and have this information by May 6th.
    g. A request was made to put all of the strategy and planning items for follow-on funding together in the final agenda.

4. John Gaudet indicated that a website will be demo'ed at the May 6 meeting by either Pat Helles or himself. Also, he asked that all participants of the upcoming meeting (especially faculty) give some thought about how they'd like to proceed and to forward these ideas to him for inclusion in the agenda.

John Gaudet
Research Professor
UNM

TELECON AGENDA

THURSDAY, APRIL 16, 2009

T= 12:30pm (PST), 1:30pm (MST), 3:30pm (EST)

T: Opening Remarks --- John Gaudet

T+5: Information about May 6th Meeting --- John Gaudet

T+10: Agenda Items for May 6th (strawman) --- John Gaudet

T+20: Changes/additions to agenda --- All

T+40: Final remarks

T+45: Adjourn

Center of Excellence for High Energy Lasers
Meeting

May 6, 2009

Marriott Pyramid Hotel
Albuquerque, NM
Marbella Room
2 – 5 PM

Draft Agenda

1400	Welcome	John Gaudet
1410	Program Manager Remarks	Bob Barker
1420	Proposal Strategy Options - Joint/Separate - Add schools: OSU, UCF, WS, Emory, etc?	All
1445	Review of Potential Thesis Topics	All
1515	Break	
1545	Website Demo	Gaudet/Helles
1600	Discussion of COE Follow-on Decisions - Schedule - Assignments	All
1645	Recruiting More Students	
1700	Adjourn	

Notes from Meeting
Center of Excellence for High Energy Lasers
May 6, 2009

1. Individuals who were able to join us in person for this meeting were: Scott Teare, Roy Hamil, Glen Perram, Tony Hostutler, Luke Lester, Eugene Bednarz, Wally Clark, and John Gaudet. Bob Barker was able to join us by telephone for the second half of the meeting. The agenda for the meeting is attached.

2. John Gaudet explained that Bob Barker, Program Manager, would be joining us by phone later in the meeting. He also explained the purpose of the meeting; viz., to review the options for the COE for procuring follow-on funding beyond FY2010.

3. A lot of the initial discussion centered on the need to brief Brendan Godfrey, AFOSR director, about the current status of the COE. Tom Hussey, AFOSR Chief Scientist, happened to be attending the JTO MRI Review and several COE members had a discussion with him. Brendan believes that the COE experiment has been a failure, but he has not heard about the recent successes and does not know current status. Therefore, Tom Hussey suggested that some AFRL/RD folks give him an update. A plan to prepare a list of students, and a talking paper about the COE was discussed. John Gaudet volunteered to prepare a strawman document for Glen, Roy, and Gene (who will be in D.C. in two weeks) for their use. *(FOLLOW-UP SINCE 6 MAY: Glen et al. were not able to get on Brendan's calendar so this meeting has been cancelled.)* Another avenue of support discussed would be for Scott Teare to approach Van Romero at NMT about our needs at the COE. John Gaudet will provide Scott with the ammunition about the COE in order for him to do this soon.

4. Luke Lester presented his information about an US Army SMDC BAA that was brought to his attention by Tom Shay (not present at the meeting). This BAA is posted on the COE private website for downloading (see below). There was a lot of discussion about our ability to interest the Army in funding the COE and whether a student-centered proposal qualifies for the BAA. In fact, an Army SMDC person (name??) was contacted about the BAA at the JTO Review and indicated that such a proposal would not have much of a chance for funding. Nonetheless, some suggestions were made to further explore this option; e.g.; contact Tom Shay to find out more details about what might be acceptable, check with Larry Altgibiers at Huntsville to see if he knows anything about their BAA process, make contact with West Point researchers, talk to SMDC directly [technical POC for the BAA is: Barbara Cantrell, U.S. Army Space and Missile Defense Command, New Initiatives and Innovations Division, ATTN: SMDC-RDT-I, PO Box 1500, Huntsville, AL 35807-3801, at telephone (256) 955-2137, e-mail, barbara.cantrell@smdc.army.mil.] Luke Lester will continue to pursue this option and has set a deadline for mid-June to submit a white paper to SMDC. One possible topic is to target the 50° C pumping diodes in DPALS. Luke's current students, however, are likely going down the path of fiber amplifier research. The expectation is that this white paper preparation is a good exercise to perform even if SMDC rejects it because we should be able to use it for future proposals. Luke presented a slide about the SDMC BAA with a few questions brought up for discussion about our approach towards a successful proposal to the Army (see attached). Wally Clark indicated that RDL would be willing to try for a letter of support from RD that could be used in the Army proposal.

5. Other options for funding were discussed. Although the JTO folks that were invited to this meeting were not able to attend (Don Seeley and Harro Ackermann), Tony Hostutler found out that another MRI Call for Proposals will be out in early 2010. The timing of this Call is about right for us to get new grants established for UNM and NMT before the current AFOSR grant runs out in July 2010. However, the topics won't be announced until the call is made (Feb/Mar 2010??). Another option briefed by Luke Lester is to submit Phase II SBIR proposals in micro/nano-machining, two-photon microscopy to receive individual grants.

6. Bob Barker joined us mid-meeting and emphasized that although there is no chance for another extension to the UNM AFOSR grant, if some COE students are facing a funding gap between the end of the grant (July 2010) and their graduation dates, the individual advisors should contact him well in advance so that he can try to use end-of-year (and fallout) funds to keep these students' tuition and stipends paid. He also suggested that either Howie Schlossberg or Mike Berman be the program managers at AFOSR who would likely consider additional AFOSR grants for COE topics in the future.

7. Scott Teare then briefed us on the status of the COE program at NMT. See the attached slides. He provided us with the great news that a new M.S student and a new PhD student are likely to start with the COE this summer. Their research topics will center on DPALS work and wavefront sensor development. More info can be found in the briefing.

8. John Gaudet gave a short briefing about the COE Website internal features for sharing files without the need to use email. The full briefing is attached to this note.

9. The actions that came out of this productive meeting were:

    a. John Gaudet will develop a talking paper on the accomplishments of the COE for use by the team (Roy, Gene, and Glen) that will visit AFOSR (Brendan Godfrey) and for Scott Teare's use in discussions with Van Romero.

b. Luke Lester will prepare a white paper to submit to the Army by mid-late June. This will be collaborative with AFIT and NMT. The RDL staff (Gene, Tony, and Wally) will coordinate a letter of support for the proposal.
c. Scott Teare will see about getting political support for the COE through his contacts at NMT.
d. Roy Hamil will work with Gene Bednarz, Glen Perram, Tom Hussey, and Bob Barker to make sure that Brendan Godfrey is made aware of the recent successes of the COE.
e. The Army POC for the SMDC BAA will be contacted (by Luke and/or RDL?) to discuss our proposal. Other Army contacts will also be sought out (Larry Altgilbiers, West Point faculty, etc.)

10. The meeting was adjourned at 5:00 PM. Our thanks goes to the JTO for allowing us to use a room at their meeting and providing us with full support (phone, projector, screen, coffee, etc.)

John Gaudet
Research Professor
UNM

Notes from Teleconference
Center of Excellence for High Energy Lasers
August 12, 2009

1. Individuals who were on this call were: Robert Barker, Scott Teare, Roy Hamil, Tony Hostutler, Gene Bednarz, Wolfgang Rudolph, Luke Lester, and John Gaudet. Glenn Perram and Wally Clark were unable to join us.

2. Bob Barker: Bob informed us as to status of next year's (2010) funding. He said that he is in the process of orderly phasing out of the laser COE in his portfolio. He does have ready the last increment (~$230K) ready to go. Of course, congress must first approve a DOD budget. However, even if a continuing resolution is needed, Bob will be able to ship out to UNM about 80% of the total. AFIT may be in a bit of a bind next FY regarding COE funding since their COE direct funds expired earlier this year. Consequently, Glenn will receive only about $62K in FY2010.

3. John Gaudet discussed the latest UNM student recently recruited. Omar Qassim has worked at the COE as a DE scholar this summer. He has completed most course work for his M.S. and has already started research at the COE on dimer lasers. He is joining the COE as a UNM grant student starting with the fall semester and his advisor at UNM is Wolfgang Rudolph in Physics & Astronomy. Bob asked us to encourage students to consider all of the NRC and defense fellowships that are now available, especially since money has been increasing for these. Luke Lester also suggested the NSDEG (National Defense Science and Engineering Graduate) Fellowships. (see http://ndseg.asee.org/ Application deadline is shown as January 5, 2009 so website is not up-to-date.) Luke seems to have some experience with these opportunities.

4. Dave Hostutler gave us an update on student activities during the summer at the COE labs. Omar, of course, is working on the dimer research which is part of a requirement for an MRI project with AFIT's Glenn Perram in the lead. Nate Zameroski has completed work on a paper detailing his PhD thesis and is now in AF review. Tony has had several university scholars working at the COE on a number of topics including flow visualization, and a narrow band, high power laser source. Paul Jones from AFIT will be arriving soon at Kirtland to work on his thesis and Tony has been preparing the test setup.

5. Luke Lester discussed his COE student status. Both (Nish Patel and Furqan Chirgah) have been working with Tom Shay and Craig Robbin in RDL on the fiber amplifier program. Since this lab space is getting rather crowded, with many experiments underway, it appears that Nish will transition to pump lasers with Tom Shay this fall. He will look at ways to pump Rb, Yt so that they are more temperature insensitive. Furqan will continue with Craig on the fiber amplifier program. (Also, Robert Shaw is an undergraduate. He might be Mechanical Engineering and is a sophomore.)

6. Scott Teare at NMT has 6 students (2 are undergrads) in his lab. Ted Shuler is working on wave front sensing with respect to lasers. Lindsey ??? has talked to Tony for thesis topics. Hopes to graduate in Spring 10. Brianna Cline (finished MS) will show up at Kirtland to talk to COE folks. Scott will be meeting with a Physics student who could be a new prospect for the COE.

7. Roy Hamil and Gene Bednarz indicated that they recently discussed the successes of the RDL COE with the RD Director, Sue Thornton. She wants to have a more detailed briefing about the COE sometime in the future. The preparations that we made for a possible briefing to

the AFOSR Director, Brendan Godfrey, should be helpful in getting ready for this. Gene Bednarz will take the lead in setting up a date and putting together material for the brief. Bob Barker indicated that he would like to participate via conference call, if possible.

8. John Gaudet opened the discussion about new proposals for the COE beyond the AFOSR grant (expiration 31 July 2010) by informing everyone that Luke Lester (who was planning to prepare an initial white paper for a COE extension for the Army BAA) had to spend most of his time on stimulus proposals to replace funds cut to CHTM at UNM. Now that this project is finished, Luke will concentrate on this paper. He has already some information from other COE players, but will need more. He hopes to circulate a draft by mid-September. Bob Barker reminded us not to forget about NIH and NSF opportunities. Luke discussed his stimulus money proposal experience and indicated that it is tough and crazy system and that he is not aware of any opportunities for stimulus funds from the DOD. Luke raised the question about DURIP proposals for the COE and that whether Bob would entertain any? Bob said that he only gets 2 or 3 approved every year and that the competition from his HPM PI's is fierce. He said that very infrequently extra funds are available so we should send any previously prepared proposals to him in case AFOSR has a banner DURIP year. John mentioned that there might be end-of-grant money available for some equipment.

9. The last topic on the agenda was about the annual report for AFOSR. Bob Barker suggested that this year only the required one page format was needed. Last year, John submitted two reports, the one page version and a more detailed summary of COE progress. He also suggested that UNM could include the AFIT COE work at our (UNM and AFIT) discretion. John will send out the format for the annual report to everyone so that he can compile the information to be included. It is due to AFOSR by the end of August.

10. For miscellaneous items, Tony Hostutler mentioned the student seminar series which began last spring at AFRL. He said that they will begin again in the fall semester. John suggested that NMT students participate if/when they can and Scott Teare thought this would be a good idea.

11. Finally, John brought up student participation at future conferences. The next two likely opportunities are the DEPS conference in San Antonio in November and the High Power Laser Ablation meeting in Santa Fe next April. There will certainly be UNM student participation in both. It is not known which conferences AFIT will support (likely DEPS) this time around.

12. Bob suggested that we have more frequent conference calls (hadn't had one since our meeting in May), so our next call will be in the latter part of September. It will focus on the draft proposals for our COE follow-on effort.

John Gaudet
Research Professor
UNM

AGENDA

WEDNESDAY, AUGUST 12, 2009

T= 8am (MDT), 10am (EDT)

T: Opening Remarks --- Bob Barker

T+5: UNM new students/prospects --- John Gaudet/Wolfgang Rudolph

T+10: Current UNM student activities --- Tony Hostutler/Luke Lester

T+15: AFIT students' progress --- Glen Perram

T+25: NMT students' status --- Scott Teare

T+35: Options/Status of follow-on proposals --- All

T+50: COE Annual Report Requirements --- John Gaudet

T+55: Miscellaneous Items --- All

T+60: Adjourn

Notes from Teleconference
Center of Excellence for High Energy Lasers
September 24, 2009

1. Individuals who were on this call were: Robert Barker, Scott Teare, Tony Hostutler, Glenn Perram, Wally Clark Gene Bednarz, Luke Lester, Major Cliff Sulham, and John Gaudet. Roy Hamil and Wolfgang Rudolph were unable to join us. Major Sulham was invited to present a brief report on his PhD research (see attached, last page).

2. Bob Barker: Bob started the conference with the good news that he has submitted all necessary paperwork to implement Option 4 of the UNM grant for extension and the remaining funds (~ $230K). And, Bob mentioned that the 3rd-year increment of "student funding" for AFIT is also being processed..

3. Wally Clark spoke for RDL and told all that Tony Hostutler will be the RDL lead on the COE for the rest of this year and next year, at least until a new RDL division chief is named. Wally is moving to the microwave division until his replacement can be found. Wally will still be a strong advocate for the COE. Wally will likely not leave until early next year.

4. Major Cliff Sulham (AFIT). Major Sulham gave us a short presentation "Blue Alkali Lasers Pumped by Two Photon Absorption."* He presented the experimental results which demonstrated that the blue spot detected in alkali lasers could be explained by two photon absorption. Glen Perram expressed optimism that these results may give rise to new research topics in the future.

5. The status of UNM students were presented by Tony Hostutler and Luke Lester. Nish Patel is studying optical gain in quantum materials for diode pumping. He'll be modeling/measuring diode lasers at 796 nm to try to increase efficiency. He is taking a problems course this semester with Luke. He might be able to give a presentation fairly soon on a conference call. Luke is going to get some help on this topic from a new postdoc (McKinnerny). Furqan Chiragh is still studying Yt fiber amplifiers with Tom Shay at AFRL. John Gaudet suggested that it may be time for Furqan to update all of us on his progress in this area. For example, has he selected a thesis topic yet? According to Tony, Nate Zameroski is nailing down the procedure for his pressuring broadening measurements in methane and then will do ethane. Omar Qassim is taking the laser course this semester at UNM and is focusing his laboratory work on Cs dimers. He has done the Frank Condon factor simulations and is preparing to do gain measurements on the Cs dimer system. He also will be making a DEPS conference presentation based upon his summer scholars' work at the DPALS facility.

6. Scott Teare updated us on the status of NMT students. Two of his undergrads are looking at Tony's proposals to pick up as a senior design course project. Lindsay Quarrie is the new PhD student (Mech. Engineering) who will be working at the DPALS lab to devise a coating that is resistant to alkali materials. Ted Shule is an MS student at NMT and is looking at an optics system to develop.

7. Glen Perram gave us his update. He will be a the JTO MRI review next week in Albuquerque. It will be an important review for him since his MRI projects are up for renewal. Three of his students will be going to the DEPS meeting in San Antonio. He also has plans for students at the Photonics West Conference in January and the Santa Fe meeting in April. He informed everyone about the Paul Jones situation. Paul was supposed to be at AFRL and UNM this fall doing his research and taking courses. But personal issues prevented him from coming to New Mexico. Instead, he will try to finish up at AFIT. Glen has also identified four new people to come out to AFRL/Kirtland in the next several months. One of them may be for the long term.

8. The last major topic was the status of our future funding plans. I provided my thoughts which are essentially that while we would like to get support from somewhere to keep the UNM and NMT students funded, it is not likely that a vehicle can be found which replaces the AFOSR funding in its entirety. Therefore, each professor/advisor should start now to pursue new research proposals that students can be put under with and they should be linked to AFRL/RDL for some of the students' research. There is a Homeland Security graduate level opportunity that can be pursued. The DOD SMART fellowships are an obvious option that Luke will likely use to get Nish/Furqan to apply. It is also possible that the PALACE KNIGHT/SENIOR KNIGHT programs may be re-instituted. But, Bob Baker could not confirm this. The NDSEG fellowships are also available but they are harder to get that the SMART program. Their advantage is that there is no commitment to work for the government with the NDSEG and no government lab work is necessary. The SMART scholarships have both caveats attached to them. Another possibility is that JTO topics will be released in the Nov/Dec timeframe. As a last resort, Bob has agreed to consider proposal(s) which would only cover the cost of existing COE students that need a couple semesters to finish their work. We agreed that this request must be in to Bob no later than April 2010. Tony pointed out that in order for the COE to work, doing research at the AFRL labs is a key requirement.
9. Miscellaneous. Scott Teare provided John Gaudet with the contact information for the NM Optics Industry Association. They may be able to help the COE in our future resource needs. John agreed to contact Ed Spivak to investigate.

10. We agreed to hold another conference call in late October or early November. We will try to have another student presentation at that time.

John Gaudet
Research Professor
UNM

AGENDA

THURSDAY, SEPTEMBER 24, 2009

T= 1 PM (MDT), 3 PM (EDT)

T: Opening Remarks/Update --- Bob Barker

T+5: UNM grant status update --- John Gaudet

T+10: Special Presentation, "Blue Alkali Lasers Pumped by Two Photon Absorption"* --- Major Cliff Sulham, AFIT

T+20: UNM student status --- Tony Hostutler/Luke Lester

T+25: NMT student status --- Scott Teare

T+30: AFIT student status --- Glen Perram

T+35: Status of follow-on proposals --- Gaudet/Lester --- All

T+55: Miscellaneous Items --- All

T+60: Adjourn

Notes from Teleconference
Center of Excellence for High Energy Lasers
October 30, 2009

1. Individuals who were on this call were: Robert Barker, Tony Hostutler, Glenn Perram, Wally Clark, Gene Bednarz, Luke Lester, Roy Hamil, Furqan Chiragh, and John Gaudet. Wolfgang Rudolph and Scott Teare were unable to join us. Furqan Chiragh (UNM student) was invited to present a brief report on his PhD research (see attached, last page).

2. First up, Furqan Chiragh gave his talk on the research he plans to do at RDL for his thesis. He has spent this past summer working at the laser fiber amplifier test bed to get familiar with the experiments and equipment in use at the lab. He described the experiments and work being done in the lab and indicated that he is leaning towards a project involving the laser guidestar challenge. Current plans are for him to research use of photonic band gap fibers to address this problem. Bob Barker had questions about the use of long fibers (kilometers) engineering and the problem of temperature handling. Furqan is Luke Lester's student at UNM's Center for High Technology Materials (CHTM).

3. Bob Barker: Bob limited his remarks to the status of the FY2010 DOD budget. DOD is currently operating on another continuing resolution authority (CRA). It is likely to last until 15 December 2009. Bob does not feel that this status should affect the exercise of Option 4 on the UNM grant since the action is not a new start and there is (80%) authority to spend money. However, John Gaudet indicated that UNM is taking precautions to spend "at risk" beyond the end of the current grant money (30 November) just in case. Bob did have a brief conversation with Glen Perram regarding AFIT funding from AFOSR which could be impacted by the CRA. Glen said that as long as some $$$ are available (AFOSR or JTO) by 1 January, he would be OK. Wally Clark also discussed the status of RDL funding. Apparently, current language in the DOD budget will shut down the gas laser program (part of ABL downsizing), cutting RDL's budget by several million dollars. At this point, Wally does not plan to cut the COE funding in FY2010 but the cuts have not yet hit AFRL and beyond FY2010 is an unknown at this time.

4. Luke Lester: Luke updated us on the status of efforts to find replacement funding for the UNM COE grant next year. The latest activity has come from AFOSR (Howie Schlossberg). He may be interested in supporting certain COE topics for a possible follow-on to the current COE grant at UNM. This would likely involve topics that CHTM would be interested in. There also was a discussion about the UNM fiber draw tower and the fact that RDL must rely on the Denmark firm, Crystal Fiber, to produce needed fibers for their research. The only capability lacking to replicate this function at UNM is a pre-form lab. It has been suggested that UNM vie for a DURIP grant to get the necessary capability. Bob Barker expressed enthusiasm for Howie's interest in the COE and suggested that a good approach for AFOSR and UNM would be to pursue a one-, or two-year add-on to the current grant under Howie's leadership. Luke then discussed the MDA BAA opportunity that was brought up last month. He has talked to the program manager and discovered that ITAR restrictions on this BAA would probably be too tough to handle effectively for UNM. However, AFIT would not have problems with ITAR so this BAA could be a possibility for Glen to pursue for his COE students.

5. Wally reiterated that RDL is committed to the success of the COE. John Gaudet mentioned that based upon last month's suggestion from Scott Teare that he contact Ed Spivak at nmOptics about funding opportunities through industry, he reported that there is no immediate source available. However, their plans to build a consortium of optics industry, government and education partners could provide the COE with useful connections sometime in the future. Wally indicated a possibility that RDL could play a role here. Especially since the Chief Engineer of RD, Cindy Kaiser, is in contact with Ed Spivak about these plans. Finally, Tony Hostutler will be checking out Ron Kaspi's interest in establishing new COE students in the mid-IR (semiconductor lasers) technology.

6. Glen Perram: Glen told us that three AFIT students are planning to come to Kirtland AFB between Thanksgiving and Christmas to conduct research at the DPAL's laboratory. Since Glen and Tony will be at the DEPS Symposium next week, details of their visit and experiments planned will be finalized then.

7. Finally, John Gaudet gave an update on the start of a new area of research for COE students: disk lasers. A meeting was held in mid-October to discuss signing up Natasa Vretenar at CHTM under the advisement of Ganesh Balakrishnan. He indicated that the existing funds support the ability to sign her up for the upcoming Spring semester and one summer term before the end of the grant. She is likely to work on a thermal management problem in disk lasers. The RDL contact will be Tim Newell.

8. Bob Barker suggested that the next teleconference should be sometime in January. We agreed that unless an emergency required otherwise, we would conduct our next teleconference before the start of the spring semester in mid-January.

John Gaudet
Research Professor
UNM

AGENDA

FRIDAY, OCTOBER 30, 2009

T= 1 pm (MDT), 3 pm (EDT)

T: Opening Remarks --- Bob Barker

T+5: Student presentation: "COE work being done at AFRL at KAFB*," Furqan Chiragh, UNM

T+15: Progress on COE grant follow-on – Luke Lester/Glen Perram

T+25: AFRL COE status --- Wally Clark/Tony Hostutler/Gene Bednarz

T+30: AFIT COE status – Glen Perram

T+35: Potential new UNM student --- John Gaudet/Luke Lester

T+40: Miscellaneous items

T+50: Adjourn

Notes from Teleconference
Center of Excellence for High Energy Lasers
January 22, 2010

1. Individuals who were on this call were: Tony Hostutler, Glenn Perram, Roy Hamil, Wolfgang Rudolph, Scott Teare, and John Gaudet. With several members not able to call in today, the agenda for the meeting was shortened to about 30 minutes.

2. John Gaudet announced that John Luginsland is the new program manager for the UNM COE grant at AFOSR. John L. was unable to join us on the call, however. John G. also updated everyone on the status of Option 4 which has not yet been implemented by AFOSR. He has been in contact with John L. and Bob Barker about this. AF has just released FY10 money to AFOSR this week and the grant $$$ should begin to flow very soon. John G. must wait until Option 4 is in place before he can send New Mexico Tech a no-cost extension so Scott Tear can continue to use the funds authorized for him through 31 July 2010.

3. Glen Perram also has not received AFOSR funds for his COE activities for the year. Fortunately, he has some JTO money that he can use for now. Glen briefly described the work his students have done over the past month, or so. They have completed experiments at Kirtland and are concentrating on papers for the conferences next week (SPIE Photonics West) and for the Laser Ablation Conference in the spring. To summarize papers/conferences : 3 DPALS papers at Photonics West conference next week. HP Laser Ablation conference papers due soon (4 papers due). Just completed tests with Tony before XMAS with some visiting (Kirtland) students. Glen will attend the JTO MRI review on 16 Feb where he will hopefully receive the go-ahead for years 4&5 on his JTO grant. This will be extremely important for the AFIT COE program to continue.

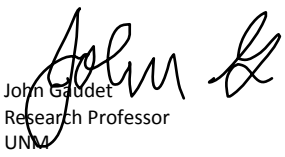
4. Tony Hostutler briefed us on Nate Zameroski's work. He is about to finish the first phase of his research and will start experiments on the last phase of his research soon. Omar Qassim has had some problems with the dimer work and is working with Tony to resolve them.. He believes that Luke's students have been on vacation recently. Tony also reported that a new group of NMT students have arrived for their undergraduate project work. John G. is working with them to get their laser eye exams accomplished so they can work in Tony's lab.

5. Scott Teare discussed his students' status which has been affected by the lack of COE funding available so far. Lindsay Quarrie is spending time working on his qualification exams for the PhD and preparing his dissertation outline and first few chapters..

6. John Gaudet briefly summarized the situation with Luke Lester's initiative to continue a HEL COE with Howie Schlossberg at AFOSR. It is not clear if this would be proposed as a new grant to UNM or as a continuation of the existing grant. In any case, an attempt will be made to include the work the legacy COE students have started as well as some new tasks.

7. Roy Hamil mentioned that the DE Systems Symposium is in desperate need of abstracts. See the DEPS website (www.deps.org) for details.

8. The meeting was adjourned after John Gaudet recommended that another teleconference call be held in a few weeks to provide current updates on the follow-on grant efforts status.



John Gaudet
Research Professor
UNM

AGENDA

FRIDAY, January 22, 2010

T= 2 pm (MST), 4 pm (EST)

T: Opening Remarks from Program Manager --- Bob Barker (vice John Luginsland)

T+5: Status of UNM COE grant Option 4 --- John Gaudet

T+10: AFRL COE status --- Tony Hostutler/Gene Bednarz

T+20: AFIT COE status – Glen Perram

T+30: NMT COE status – Scott Teare

T+40: Follow-on funding efforts – Luke Lester/Wolfgang Rudolph/Scott Teare/Glen Perram

T+55: Wrap-up, future conference calls – All

T+60: Adjourn

Notes from Teleconference
Center of Excellence for High Energy Lasers
March 3, 2010

1. Individuals who were on this call were: John Luginsland, Tony Hostutler, Glenn Perram, Wolfgang Rudolph, Scott Teare, Luke Lester, and John Gaudet. Gene Bednarz was not able to call in today.

2. John Gaudet introduced John Luginsland, the new program manager for the UNM Grant, who is taking over for Bob Barker who is retiring soon. This was the first conference call that John L. was able to join so he presented his view of the rest of the grant period. Primarily, he sees his main task to be insuring the smooth transition from the UNM grant on the COE to a new AFOSR grant with Howie Schlossberg as the Program Manager. John L. then talked about the status of Option 4 on the UNM grant. He signed the Purchase Request last week and knows that it has moved over to the contracting office. So, it should be soon. John Gaudet pointed out that the delay is mostly affecting Scott Teare's PhD student (Lindsay Quarrie) who can't return to the COE Kirtland labs until the extension is approved. John L. also wanted to know from Glen Perram if he has received his funding documents yet. Glen responded that he hadn't. John L. will do further checking on this.

3. Tony Hostutler of RDL briefed us on the current students conducting research at RDL facilities. Nate Zameroski has just completed a new paper on rubidium and it has been submitted for public release review. Nate will continue working with DPAL demonstrators using hydrogen and deuterium. Omar Qassim is finishing up his experiments and the first chapter of his Masters' thesis. Natasa Vretenar is getting established in her RDL lab (just started with RDL this semester). There are some modifications to do for her high power semiconductor disk laser research. Tony pointed out that through summer internships and the DE scholars program he should have 4 or 5 new students working at the COE this summer. Finally, Nishant Patel is working with the Luke's new postdoc and he and Furqan Chiragh are in the process of preparing new proposals for their research to be submitted to Howie Schlossberg.

4. Scott Teare. Scott mentioned that his PhD student, Lindsay Quarrie, is continuing to write early chapters for his dissertation while working on computer models as he waits for the COE grant to be continued. He will then return to Tony Hostutler's lab to continue his research.

5. Glen Perram. It has been a busy time for Glen and his COE students. They gave three papers at Photonics West. And, four papers were submitted to the Laser Ablation Conference in Santa Fe this April. Glen will have three (MS) students graduate at the end of March. Glen then proceeded to give brief sketches about each of his students' progress and work that they are doing for the COE. He did mention that several new projects are planned that are dependent on getting his JTO MRI program renewed for two more years starting this September. Maj. Solomon did very fruitful work over the holidays at the COE lab on Kirtland and his analysis will be completed shortly. Tony Hostutler should review these very interesting results. Finally, Glen pointed out that one of the undergrads that visited Kirtland during these experiments was so impressed with the work going on in RDL that he decided to continue his studies in graduate school.

6. Luke Lester. Luke had two meetings with Howie Schlossberg recently to discuss a new grant for the COE students to ensure that they will be able to complete their degrees. They decided to go with a 2-yr proposal (new grant not called a "COE") that would fund the existing students (plus one new one that Howie agreed to in the mid-IR laser area) and also create some time for getting prepared for the new

round of COEs that AFOSR expects to start this fall. Six tasks have been identified (five UNM/ one NMT) . Luke needs info that he requested from the student advisors by March 10 to meet AFOSR deadlines. The tasks, associated students, UNM PI, and AFRL advisor are:

Task	Student	University / Dept	Faculty Advisor	AFRL Advisor
Hollow core fiber amplifier	Furqan Chiragh	UNM / ECE (CHTM)	Luke Lester	Tom Shay
High temp., high efficiency diode pumps for Yb-doped fiber	Nishant Patel	UNM / ECE (CHTM)	Luke Lester	Tom Shay
DPALS – quenching and radiation trapping studies	Nate Zameroski	UNM / Physics & Astronomy	Wolfgang Rudolph	Tony Hostutler
High power semi – conductor disk laser	Natasa Vretenar	UNM / ECE (CHTM)	Ganesh Balakrishnan	Tim Newell
DPALS - Alkali resistant coatings	Lindsay Quarrie	New Mexico Tech / EE (Materials Eng.)	Scott Teare	Tony Hostutler
Mid – IR semiconductor laser	new student	UNM / ECE (CHTM)	Steve Brueck	Ron Kaspi

7. JTO MRI BAA. The new BAA just got released at the beginning of March. The deadline for proposals is April 20th. Both AFIT and UNM/Wolfgang Rudolph have existing MRI's. Glen Perram hopes to get his extended by two years. Currently, AFIT is not eligible to submit under the new BAA, but John L. says that this "glitch" is being worked and should be fixed soon (a mistake). So, AFIT may submit new proposals (in sensors and in the solid state materials area (Sal Cusumano). Wolfgang Rudolph says that he has 3 of 4 possible topics to submit for the new MRI and is considering his options/partners.

8. John Luginsland said that he would talk to Howie Schlossberg about the timing of the new grant. If the new grant can't be put in place by August 1st, there may be students who are not covered for their research during part of the summer. This issue needs to be addressed in plenty of time to make sure that students can find some alternate means of funding.

9. The next conference call will be in mid-April just prior to the Santa Fe meeting on Laser Ablation for which AFIT will have several talks/posters. We agreed that on this next call we will have a student technical presentation on his thesis work. One suggestion is to use this talk as a dry run for Santa Fe.

10. Meeting was adjourned at 1445 MST.

John Gaudet
Research Professor
UNM

AGENDA

WEDNESDAY, MARCH 3, 2010

T= 2 pm (MST), 4 pm (EST)

T: Opening Remarks from Program Manager --- John Luginsland

T+5: Status of UNM COE grant Option 4 --- John Gaudet/John Luginsland

T+10: AFRL COE status --- Tony Hostutler

T+15: AFIT COE status – Glen Perram

T+20: NMT COE status – Scott Teare

T+25: New AFOSR Grant w/H. Schlossberg – Luke Lester

T+40: New JTO MRI BAA – Wolfgang Rudolph, Glen Perram, Scott Teare

T+50: New items/discussion – All

T+60: Adjourn

Notes from Teleconference
Center of Excellence for High Energy Lasers
May 5, 2010

1. Individuals who were on this call were: John Luginsland, Glenn Perram, Luke Lester, Roy Hamil and John Gaudet.

2. This was an informal conference call with no detailed agenda. I just wanted to discuss the status of the new efforts for the legacy students and the close-out report for the UNM grant.

3. Luke updated us on the new proposal to AFOSR. He has talked to Howie about the draft version submitted and was told to go ahead and submit a formal proposal with budget. Tom Hussey, AFOSR's Chief Scientist, did review the draft and stated that he didn't want to add the new student for Ron Kaspi (RDL) being planned in the draft proposal. In order to keep the costs down and within AFOSR's available funds, the following plan was developed. Nate Zameroski and Lindsay Quarrie of NMT will be supported for one year. Nish Patel and Natasa Vrentnar will get two years of support. Finally, Furqan Chiragh has reached an agreement with Tom Shay of RDL to work as a contractor and continue to conduct his research. Luke told us that the formal proposal is in to H. Schlossberg and awaits AFOSR action. He is optimistic about the grant's chances, but when the start date will occur is still an open question. Luke will talk to Howie S. to find out what a realistic start date might be.

4. Glen Perram reported that he did receive the 4th and 5th year funding on his grant from JTO which should start in September. This is good news for AFIT's DPALS students. Also, he submitted a new proposal on the lethality topic to JTO this year. The University of Virginia is providing theory support and AFIT will be doing spectral imaging of damage caused by a variety of high energy lasers. He should know the status of the proposal next month. Finally, it appears that John L. never received Glen's email about the $60K Bob Barker planned to send to AFIT for legacy COE students. John L. thought that all of his funding actions have taken place, yet AFIT hasn't received the MIPR. Glen will resend the email as soon as he gets back to his office on Friday.

5. The last topic discussed was the plan for the UNM grant's final report which is due 60 days after the end of the grant (or October 31, 2010). The question that John G. raised about this report is the extent to which it should include the non-UNM grant activities of the COE. John Luginsland agreed that perhaps an appendix (or two) would be an appropriate place to include information about AFIT COE efforts and other students who have been part of the COE umbrella but who have not been supported by the UNM COE grant. Glen agreed that an AFIT appendix could essentially be his annual report that he routinely sends to AFOSR at the end of the year. Thus, the focus of the annual report will be the UNM and NMT students' efforts with some mention of the overall COE and its student activities within appendices of the report.

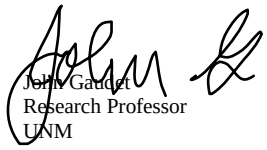
6. With no further discussion, and a agreement to try to have one more conference in 6 – 8 weeks, the meeting was concluded.

John Gaudet
Research Professor
UNM

Notes from Teleconference
Center of Excellence for High Energy Lasers
July 14, 2010

1. Individuals who were on this call were: John Luginsland, Glenn Perram, Luke Lester, Roy Hamil, Tony Hostutler, and John Gaudet. ….

2. This was an informal conference call with no detailed agenda. The main focus of the call was to let Luke Lester discuss the plans for transitioning the UNM HEL COE grant to his new grant with AFOSR (Howie Schlossberg, PM). Also, final details for the Final Report for the UNM grant needed to be discussed. This is the last conference call sponsored by the UNM COE grant with J. Gaudet as the PI.



John Gaudet
Research Professor
UNM